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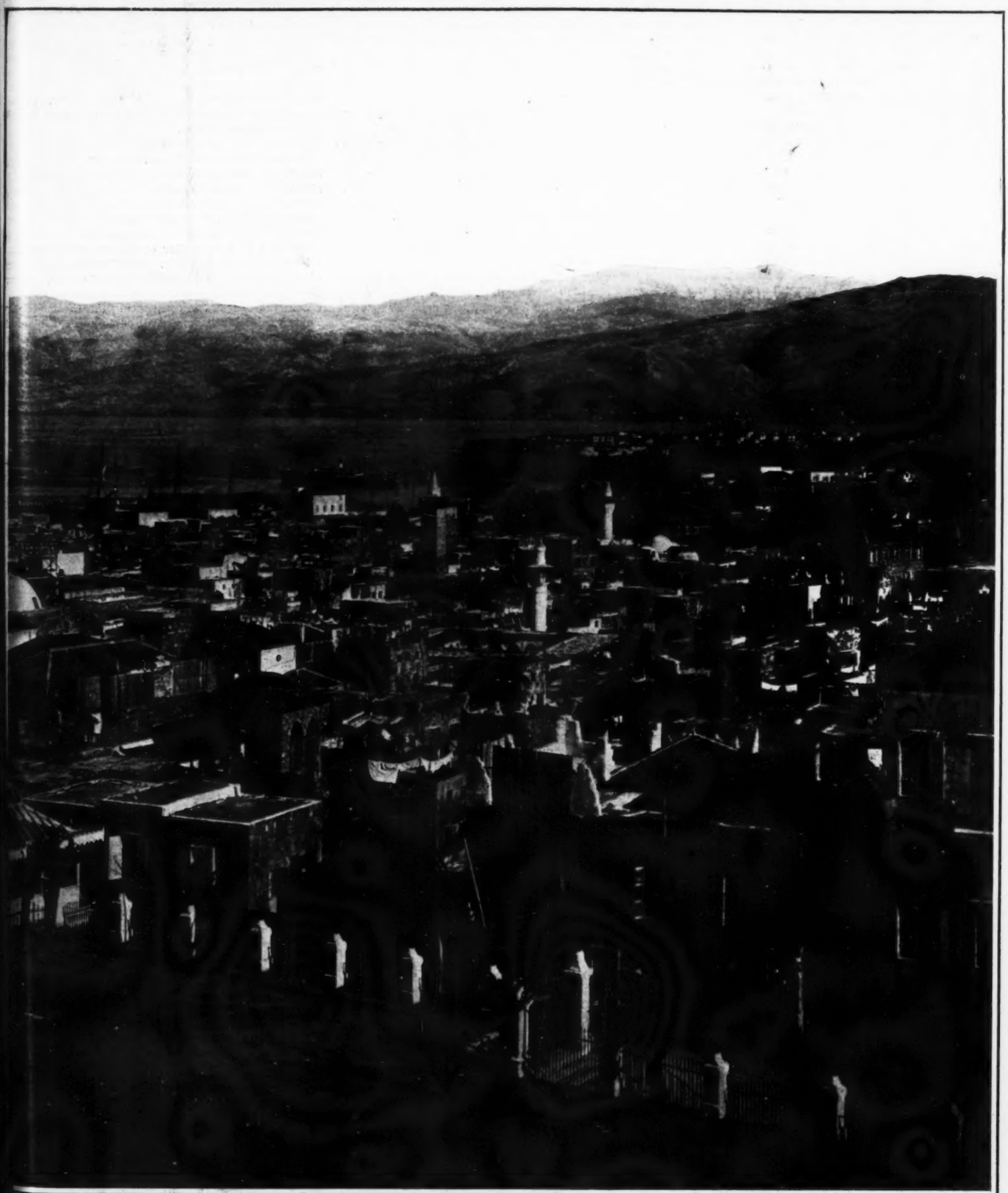


...FT, THE STARTING POINT OF THE BEIRUT AND DAMASCUS RAILWAY WHICH SURMOUNTS THE LEBANON MOUNTAINS (SEEN IN THE VIEW) BY A COGGED RAILWAY.

THE RAILWAYS OF THE HOLY LAND. [SEE PAGE 248.]

THE METALLIC STATE.

ITS MODERN PHYSICAL CONCEPTION.

BY E. E. FOURNIER D'ALBE, B.SC., M.R.I.A.

"ANY physicist who may at some future time write a history of physical theories will probably describe the present epoch as the epoch of the Electron theory. More than ourselves will he gain the impression that in science it is always the same conceptions which alternately rise and fall. He will describe with particular interest how Maxwell's continuous-medium theory was displaced by atomistic ideas. In this change, electro-chemistry has taken its full share; the doctrine of ions is completely under the sway of atomistic conceptions. But these latter were at first allowed to exist side by side with the continuous medium, without regard to their contradictions, and it was only the electron theory which eventually brought about the victory of the atomistic conceptions."*

With these words, Privy Councillor Eduard Riecke, of Göttingen, opened, last year, his address to the German Bunsen Society for Applied Physical Chemistry at its sixteenth annual meeting at Aachen, his subject being "Present-Day Views on the Nature of the Metallic State."

WHAT IS A METAL?

The division of elements into metals and non-metals is somewhat arbitrary. Substances like selenium, tellurium, arsenic, and antimony may be classed under either head, according to the properties which happen to be under consideration. Sir Henry Roscoe gives the following criteria, which are generally accepted: "All metals, with the single exception of mercury (a liquid) are solid at the ordinary temperature; they possess a high power of reflecting light, causing the bright, glittering appearance known as 'metallic luster'; they are opaque, except in the thinnest possible films, when, as in the case of gold-leaf, they allow light to pass; they are better conductors of heat and electricity than the non-metals, and, as a rule, they have higher specific gravities than these."

These properties are not, however, the properties which give the best-known metals their practical value. Malleability, ductility, strength, high melting-point, and resistance to oxidation are the characteristics which render a metal pre-eminent in its class, and distinguish it from the less workable non-metals, which render it, in fact, a desirable commodity on the metal market. It will be the business of the chemistry and metallurgy of the future to tell us how these properties can be secured and enhanced. The first step to a complete metallology is a comprehensive theory of the metallic state, and such a theory is just now being elaborated. It must put all the physical and chemical properties of metals under the sway of a general principle, and furnish a point of view from which they can be surveyed as an orderly system. At present there still remain some large areas of chaos; but much has been done to make a clearance, and to give an account of this work is the purpose of the present article.

LINES OF INVESTIGATION.

All the physical properties of metals referred to above have become the subjects of elaborate research, conducted with greatly improved instruments. They also furnish points of attack for theoretical advances. Mathematicians are busy formulating kinetic and other theories of the solid state. The optical properties of metals are studied by means of the spectroscope, the polarimeter, and the photometer. The phase rule and the theory of mixed crystals have shed a bright light on the structure of metallic mixtures and alloys. New etching and staining methods have been devised for the microscopic study of metallic bodies, and these have been aided by new micro-chemical and micro-photographic devices. Electrical apparatus for the determination of resistances has not been improved recently, but that is because it practically reached perfection years ago. But, on the other hand, the important subjects of thermo-electricity, thermo-magnetism, and the phenomena analogous to the Hall effect, have been greatly developed.

While physicists have been working in these directions, chemistry has not been idle. Liquid-air apparatus has become a common adjunct of a properly-equipped laboratory, and every substance has been brought into the super-arctic cold of the Dewar flask. At the other end of the scale of temperature, the electric furnace is freely used to prepare the most refractory metals, such as chromium, rhodium, and tungsten. Gaseous chromium and solid metallic hydrogen will probably play prominent parts in the metallography of the future. But for practical purposes, for the control of metallic properties and the preparation of useful alloys, a sound theory of the metallic state is quite as important as any instrumental device. And it is this theoretical advance to which we must now turn our attention.

* Zeitschrift fur Elektrochemie, July 15th, 1909.

ELECTRICAL CONDUCTIVITY.

The resistance of metals to the passage of an electric current was the first property which yielded itself to the new treatment. In the hands of Riecke, Drude, and Thomson it has been made to furnish valuable data concerning the intimate structure of metals. The result, briefly, is this: The mass of the metal is a kind of honeycomb, built up of metallic atoms arranged in complex structures partaking largely of a crystalline character. The caverns of the spongy mass are pervaded by what Franklin would have called "the electric fire." This is the subtle "fluid" composed of electrons, which, like the molecules of a gas, dart about in all directions, and sometimes enter into close connection with the metallic atoms. The electrons possess the elementary negative charge of electricity, while the uncombined atoms are positively charged. Hence the metal as a whole is electrically neutral, but if any considerable number of electrons should fly out of the metal, the latter would have a balance of positive electricity which would soon bring back the escaping electrons to their former allegiance.

When such a piece of metal is brought into a field of electric force, the electrons, in their free intervals, drift in the direction of the force, and this drift constitutes the electric current.

The amount by which the electrons are deflected out of their ordinary paths by the electric force depends upon the temperature. The higher the temperature, the less the deflection, since a higher temperature means, according to the dynamical theory of gases, a greater speed and kinetic energy of the molecules. The electrons behave, in this respect, like the molecules of a gas. But since the mass of an electron is about 1/3600 part of the mass of a hydrogen molecule, its mean velocity must be sixty times that of the latter at the same temperature. This means a speed of some sixty miles per second at freezing-point, and the speed increases as the square root of the absolute temperature.

Just as a cannon ball is less deflected by gravity the faster it flies, so the effect of an electric force in producing a drift of electricity is lessened by heat. Hence, in a metal, the resistance increases with the temperature.

There are other factors as well, which become even more influential in non-metallic substances. Thus, we have reason to believe that at higher temperatures there are more free electrons in the metal than at low ones, just as, in an electrolyte, there are more ions the higher the temperature. In electrolytes, which contain no free electrons, this is the governing factor. But in metals it only becomes important as a differential effect in such phenomena as those of thermo-electricity.

CONDUCTIVITY FOR HEAT.

The electrons in a metal are probably the sole carriers of heat. The atoms are fixed in position, and if heat is "a mode of motion," that motion is not, as Tyndall believed, a vibration of the atoms, but the darting about of the particles of electricity at planetary velocities.

The calculation of the thermal conductivity of a metal is even simpler than the calculation of its electrical conductivity. It is proportional to the number of free electrons in unit volume, to their mean free path, to their speed, and to their increment of energy per degree of temperature. When one side of a lump of copper is heated, the electrons at that side acquire a greater speed. This enhanced speed diffuses through the rest of the metal with the speeding electrons, and is only lost when dissipated by the Roentgen rays, generated by every electron which is suddenly stopped in its course by colliding with the atomic framework.

WIEDEMANN AND FRANZ'S LAW.

And now we come to one of the most remarkable successes of the electron theory. It was found by Wiedemann and Franz that the ratio of the thermal conductivity to the electrical conductivity is sensibly the same in most metals, and that this ratio is proportional to the absolute temperature. This law is an immediate result of the reasoning given above. The absolute temperature does not appear at all in the formula for the thermal conductivity (which does not sensibly vary with the temperature). In the electric conductivity formula, on the other hand, it figures in the denominator. Hence, the ratio of the two is proportional to the absolute temperature. The law is not strictly true; but the connection is evident at first sight. The observed discrepancies, specially evident in the cases of iron and bismuth, have sometimes been attributed to that portion of the heat which is propagated by internal radiation, and is therefore beyond the power of the electron theory. But Schuster and Reinganum have independently shown that this portion of the heat is quite negligible. The remarkable increase in resistance in the case of alloys must be connected with the binding of electrons in the groups of mixed crystals, and when, in such substances as German silver and constantan, we get a very small temperature coefficient of resistance, it is probably a matter of the density and mean free path of the electrons, which are in some way affected by the mixing of metals. Chemical rather than physical research will probably resolve this part of the problem.

THERMO-ELECTRICITY.

Thermo-electric currents were somewhat of a stumbling-block to electrical theory until Lorentz managed to give a thermo-electric couple a structure theoretically resembling a concentration cell. Then it becomes comparatively simple. Thermo-electric force is due to differences in the density of electrons—in other words, to differences in the number of free electrons per unit volume in the two metals. The thermo-electric force of a thermo-couple is, according to Lorentz, proportional to the difference of the logarithms of these densities in the two metals constituting the thermo-couple. Thus, a cubic centimeter (0.061 cubic inch) of bismuth contains only half as many free electrons as an equal volume of lead. When two rods, one of bismuth and the other of lead, are joined at both ends, and one junction is heated, a "current" passes from bismuth to lead across the hot junction. Actually, it is the numerous electrons in the lead which, under the stimulus of heat, overflow into the bismuth, which causes the current. The displacement of electrons is from lead to bismuth. It is the real current of "negative" electricity, which is equivalent to a "positive" current in the opposite direction.

The Peltier effect is capable of an even more obvious explanation. When we send a "current" through a lead and bismuth couple we are really sending an electron current from the bismuth to the lead. Practically, we are forcing electrons from a region of low pressure (bismuth) into a region of high pressure (lead). We must not, therefore, be surprised if heat is developed at the junction, as it would be in the corresponding case of a gaseous compression.

On reversing the current, we drive electrons from the lead into the bismuth, and the cooling observed at the junction may be looked upon as analogous to the cooling of a gas expanding under reduced pressure. In reality, the matter is a little less simple, as the electronic "fluid," unlike a gas, is practically incompressible. Thus, if the rods have the same diameters, a smaller number of electrons will fit into a given length in the case of bismuth than in the case of lead. It is a property of the two metals, unexplained as yet, but of fundamental importance. In any case, the electrons, being fewer per unit length in the bismuth, and yet passing in equal numbers in a given time across each section, must pass more rapidly along the bismuth than along the lead. The acceleration thus rendered necessary consumes energy, and the consequent cooling is the Peltier effect. The converse effect is similarly explained by the loss of speed of the electrons in passing from bismuth to lead.

SPECIFIC HEAT.

According to Boltzmann's law of equipartition, any energy communicated to a body distributes itself equally among the "degrees of freedom" of its constituents. This law, if true for molecular and electronic dimensions, enables us to subject the electronic theory to a crucial test as soon as we know how many degrees of freedom a metallic atom possesses. It may go into thousands, to judge from the bewildering number of spectrum lines—say, in the spectrum of iron or mercury. But in the metallic state, these degrees of freedom may be reduced to a very low figure, and possibly to zero, if the "cavern" view is the true one. In this case, we should only have to reckon with the free flying electron, which has six degrees of freedom, three of translation and three of rotation. Certainly the atomic heats of the metals uniformly indicate six degrees of freedom.

ATOMIC DIAMETERS.

The theory of thermo-electricity allows us to determine the number of free electrons per atom. The theory of electric conduction gives us the total number of free electrons. Both together give us the

number of atoms in a given volume. Knowing this, we can calculate the volume occupied by each atom, and (supposing the atoms are in contact) its diameter. It comes out as about a hundredth-millionth of a centimeter (0.000000003937 inch) and varies periodically with the atomic weight. The same result (within about 40 per cent) is obtained from Avogadro's principle and chemical behavior, on supposing that the atoms are in actual contact when the metal is at its melting point.

OPTICAL PROPERTIES.

The presence of free electrons fully accounts for the opacity of metals. They absorb light waves by allowing them to set them in motion. They follow each electro-magnetic wave; they "cushion it off" from the interior, and absorb its energy. It is only in very thin films that metals show their true colors by transmission.

Gold, which reflects yellow light, and transmits green light, thereby shows that it has a preference or resonance for certain wave-lengths. Were that not the case, it would be white, black, or gray. But resonance implies resonators—i. e., electrons bound to certain positions, and vibrating at certain definite rates. It is these which are responsible for spectra and colors and polarized light.

The subject is an inexhaustible one. But enough has been said to indicate the remarkable developments of recent metallographical science. The dream of the alchemists is not much nearer to its realization; but we are beginning to understand the metals, to "see through them," in more senses than one. Fortunately, the number of outstanding problems is such that, for some time to come, the metals are not likely to lose the fascination of the unknown.—English Mechanic and World of Science.

THE AEROPLANE IN WAR.

THE FIRST PRACTICAL TESTS OF THE MILITARY AIRSHIP AND AEROPLANE.

BY THE PARIS CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

THE grand French army maneuvers under the leadership of Gen. Michel, *membre du Conseil Supérieur de la Guerre*, began at 6 A. M., Monday, the 12th, and terminated on Sunday, the 18th of September. They took place this year in Picardy, with headquarters at Grandvilliers (Oise), the scene of action being the triangle formed by Amiens, Rouen, and Beauvais, as that wooded and broken part of the country was found best suited of all others near the coast, especially for ambushes and skirmishes. Its comparative proximity to the sea and its high grounds exposed everywhere to the severe air currents generally prevailing there in all directions were likely, besides, to best lend themselves to the very instructive atmospherical observations which formed an important part of the programme.

Gen. Meunier commanded the Blue, or "Invading" army (Third Corps), whose advance line extended to Marcus, Sarnois, Briot, and Thieuloy, while to Gen. Picquart, ex-Minister of War, was given the leadership of the Red, or "Home" Army (Second Corps), whose line extended to Demerancourt, Redderie, and Sommereux. This Second Corps was to defend Paris against attack from the Third Corps, the advance guard of an invading force supposed to have landed in Normandy and to be marching toward Rouen. In addition to the Second and Third corps, were engaged in these operations a brigade of Colonial infantry, a brigade composed of chasseurs and zouaves, besides two divisions of independent cavalry, an effective total of 60,000 men. For the first time, each army corps was provided with 30 batteries of 4 guns each, making 120 guns in lieu of 96, being thus brought nearer equality with the German army corps having 126 guns each.

The greatest curiosity attached to the results of these maneuvers, which were this year carried out upon an unprecedented scale of lavishness, mainly owing to the extraordinary progress of military aviation. The opposing generals each had for the first time at their disposal well-organized detachments of aeroplanes and of dirigible balloons, with their needed hangars, manning, repair stations, etc., all well supplied and admirably managed. Fifteen air craft took part, four aeroplanes being assigned to each corps and three being given to the Staff Headquarters, in addition to four dirigibles. The personnel of the Aviation section was as follows:

Staff Headquarters: Chief airman (*chef de groupe*), Capt. Marie.
Pilots, Paulhan and Bréguet.
Sappers, Latham and De Robillard.
Scouts (*observateurs*), Madiot, Marconnet, Vúllierme, Jost.

Second Corps: Chief airman, Capt. Hugoni.
Pilots, Mailfert, De Caumont, Aquaviva, Ménard.
Scouts, Hugoni, Sido, Baugnis.

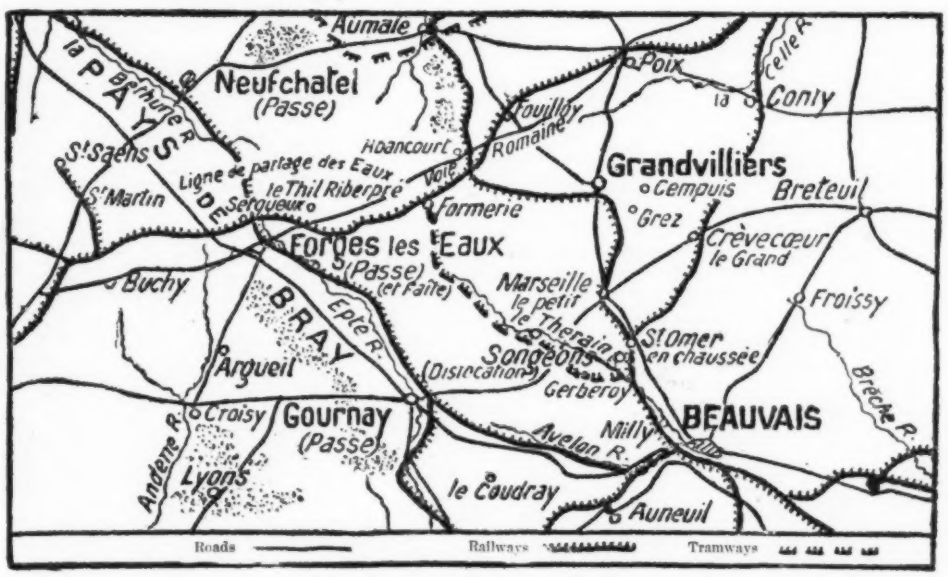
Third Corps: Chief airman, Lieut. Bellanger.
Pilots, Letteux, Bellanger, Maflois, Lafont.
Scouts, Lucca, Yence, Saunier.

Three aeroplane stations were established: one at Briot, quite close to Grandvilliers; another at Formerie, some ten miles away and quite near to the village which in 1870 distinguished itself by a splendid defense; and the third on the plateau of Poix.

For the dirigibles, "Colonel Renard," "Liberté," and "Zodiac," three immense sheds were erected at the camp Militaire, Briot-Aviation, the shed of the "Clément-Bayard II." being at Issy-les-Moulineaux. The new sheds, or hangars, although temporary, were made very attractive. One of them, 100 meters long, 30 meters high, and 18 meters wide, could be erected by 200 men in ten hours at a cost of only 200,000 francs, or forty thousand dollars. A smaller "Zodiac" was used in place of captive balloons for observations outside the sheds. A building was erected for the manufacture by new secret process of purer hydrogen gas by treatment of powdered ferro-silicon with caustic soda. This is said to have been used by the dirigibles with very satisfactory results.

Monday, September 12th.—On this, the first day of the maneuvers, began the mobilization of the aerial services.

The "Clément-Bayard II." made a smooth passage from Lamotte-Breuil, near Pierrefonds, having on board Messrs. Clément, Sabatier, Baudry, Delasser, De Jensac, Ferriar, Engelbach, Tixier, and Marshal Veilard, nine in all. It followed the route of Compiègne, Clermont, Beauvais, St. Omer, Grandvilliers, at an average elevation of 250 meters, and made the excellent time of 2 hours and 5 minutes, keeping in constant wireless communication with the Eiffel Tower and Briot-Aviation.



SCENE OF THE FRENCH MILITARY MANEUVERS OF 1910.

At 11 A. M. Lieut. Bellanger made a voyage by order of Gen. Meunier, who was desirous of ascertaining the number of troops between Formerie and Briot, while between 4 and 5 P. M. the Second Corps made two important reconnoisances, one conducted by Major Ménard and Lieut. Sido, who covered Eguennes, Sarnois, and Briot, as far as St. Maur, and the other conducted by Lieut. Aquaviva which extended over pretty much the same territory and returned via Giez and Champois.

Tuesday, September 13th.—Many ascents were made, notably by Capt. Letteux and Lieut. Bellanger, who had been ordered by Gen. Meunier to proceed in their Blériot, from Formeric, and who first landed near Broquiers, to let the enemy's biplane pass over them, then started again along the Poix road obliquely toward Conty and back by way of Crèvecœur. Also by Capt. Madiot and Lieut. Bréguet and again by Lieut. Bellanger with Midshipman Lafont. All the craft behaved admirably and circled over the battlefields with great steadiness, notwithstanding the heavy wind. The most important results were, however, obtained by Major Ménard and Lieut. Sido of the Second Army Corps, who, at 6 A. M., rose in a Farman biplane with instructions to fly over the cantonments of the Third Corps and gather all the information possible concerning the enemy's position and movements. They returned in less than two hours and at once communicated to Gen. Picquart the following report:

"At 6 passed over Thiculloy and saw three squadrons of mounted chasseurs; at 6:30, at Feuguieres, saw a brigade, accompanied by two batteries of artillery, marching toward Brombes; at 6:32, northeast of Feuguieres, saw two companies of engineers, one going north and the other northeast, to dig entrenchments; at 6:40, saw at Achy a company of infantry marching northeastwardly . . ."

Wednesday, September 14th.—This was intended to be the most interesting day of the meeting, for President Fallières, accompanied by other dignitaries, was to make his first visit, as head of state, to a *champ de manœuvres*, and the contending bodies were to first employ the whole of their artillery.

The results of examinations made by the aerial scouts were such as to twice force the commanders to change their plans of battle.

Early in the morning, Major Ménard and Lieut. Sido of the Reds started in the rain with orders to find the whereabouts more particularly of the colonial brigade belonging to the Blues. Notwithstanding a gale blowing at the rate of fully 26 miles an hour, they managed to cover all the battlefield, traveling some sixty miles in all, and, shortly after half-past seven, Gen. Picquart had their report, the most important feature of which was that the brigade was without artillery and could not therefore assume the offensive, as had been supposed. They had also noted that two of the enemy's aeroplanes had come to grief in a field close by. While they were being felicitated, a biplane, "Le Gypaëte," directed by Lieut. Paulhan, sailed over the Reds and was soon followed by another in charge of Latham, who made all sorts of demonstrations, circling around the different positions as if under examination, notwithstanding the heavy rainstorm that had set in. Latham finally came down to submit the design of the whole trip which he had traced while sailing. There appeared, in turn, a biplane in charge of Lieut. Bréguet, another in charge of Capt. Marie, and the monoplane of Lieut. Aquaviva, as well as the machines of Letteux, Mayolo, and Lafont, the last named having succeeded in almost reaching Formerie. Although four of the machines became finally disabled, they all were nevertheless able to give important information to their respective camps.

When the rain ceased, the "Clément-Bayard II.," which had before been unable to leave its shed, appeared and made a turn of the park, then proceeded

upon a reconnoissance of Grandvilliers, Sommereux, and Champois which lasted fully an hour. After landing in front of President Fallières, orders were given it by Gen. Michel to start immediately for Paris, so as to place the Army of the North in communication

L'Illustration.

AERIAL MACHINE GUN CARRIED ON AN AUTOMOBILE.

L'Illustration.

AVIATOR BREGUET AND CAPTAIN MADIOT DESCENDING FROM THEIR AEROPLANE.

with that of Paris. It left at 3:10 P. M., passing over Beauvais, St. Crépin, Pontoise, and Argenteuil, and at 5:27 landed at Issy-les-Moulineaux, having covered 120 kilometers with seven passengers in 2 hours 17 minutes at an average altitude of 400 meters. It was in constant communication with the Eiffel Tower and with Grandvilliers, and when over Beauvais and Pontoise it let go several carrier pigeons to the different camps.

The dirigible "La Liberté," piloted by Capt. Blois and Lieut. Néant, left its garage at Chalais-Meudon at 10:20 convoyed at the start by the dirigible "Colonel Renard,' which was in charge of Capts. Delassus and Bienvenu and of Adjutants Joussier, Ducasse, and Girard, and had left Issy at 10:45. Both dirigibles crossed Meru-sur-Oise, whence Capt. Delassus was forced by the heavy wind to return to Issy. The "Liberté" continued on toward Beauvais, passing that city at 12:45, and finally landed at Briot at 2:45. Later in the afternoon, it made another ascension, with Commander Labadie and Senator Raymond on board.

Thursday, September 15th.—The second half of the *grandes manoeuvres* began, the forces on each side returning to the positions they previously occupied and taking a much needed rest after the hard work hitherto accomplished.

As the weather was milder, with less wind, Lieut. de Caumont was enabled to make a very fine flight. At 4 o'clock Col. Hischauer gave him orders to convey immediately a dispatch from Briot to the headquarters at Rouen and, a quarter of an hour later, without taking even a compass, he was on his way west. At 6:10 P. M. he passed over Rouen, and a few minutes later descended in a field at Sotteville-lès-Rouen, close to the railway. The distance covered was over 50 miles. He delivered the dispatch and received another which he immediately took back to Briot.

Capt. Marie and others made voyages, and Capt. Letteux took Capt. Marconnet of the Staff Headquarters to Formerie.

The "Clément-Bayard II." carried to Grandvilliers instructions from the Minister of War in answer to the messages it had brought the day previous. This great, yellow, fish-shaped dirigible again proved indeed an impressive sight, always moving gracefully with slow majesty, especially while it circled round and round the low church spire of Grandvilliers. Its steering was simply perfect.

The "Zodiac," piloted by Comte de la Vaulx, left its hangar near nightfall and carried a message to the Third Corps, then returned to Briot-Aviation.

From a sketch by L. Sabatier in L'Illustration.

AN AVIATOR SCOUT REPORTING TO HIS COMMANDING OFFICER.

THE SOLDIER IN THE AIR

L'Illustration.

FRENCH AERIAL FIELD GUN CARRIED ON AN AUTOMOBILE. THE GUN CAN BE MOUNTED IN A FEW MINUTES AND DIRECTED AT ANY ANGLE.

Friday, September 16th.—Another notable day during which the aviation results obtained were as brilliant as any before reported, notwithstanding unsatisfactory weather conditions. The most astonishing and most satisfactory as to precision of information procured came through Lieut. Sido, who again used the Farman biplane piloted by Capt. Ménard. They had been ordered to thoroughly explore the territory occupied by Gen. Meunier's forces (*les manchons blancs*). They left Poix at 5:45 A. M., notwithstanding the strong wind, and, after covering 80 kilometers at about 500 meters' elevation, they delivered shortly after 7 o'clock to Gen. Michel the following remarkable report:

"Ordered to explore the region between Grandvilliers, Crèvecœur, and Marseille-le-Petit.

"Selected following itinerary: Poix, Eguennes, Thiculoy, Fontaine, Lavaganne, Marseille-le-Petit, Rothois, Haute Epine, Crèvecœur-le-Grand, Le Gallet, Choneuse, Les Renards, Beau Deduit, Sommereux, Dargies, St. Romain, Poix.

"At 5:56, Halloy, a company of cyclists; 5:59, Thieuloy, 16 squadrons of cavalry and 6 batteries at the southwest entrance to village; 6:05, southwest of Rothois, at northern end of the Malmifet woods, one company of infantry and two batteries of artillery marching toward Marseille-le-Petit; 6:07, Haute Epine, at northern entrance to village, one company of infantry to the right, another company to the left on the road to Marseille-Crèvecœur, another company along range number 188, and a fourth company in Haute Epine; 6:09, at intersection of the Lihns road, a squadron of cavalry posted along the edge of the woods; 6:14, on the road Crèvecœur-Marseille, south of Lihns, a squadron marching toward Marseille-le-Petit, and a detachment also in the village of Lihns; 6:16, at entrance to Lihns road to Rotangy, a squadron with two mitrailleuses marching toward Marseille-le-Petit; 6:19, at southeastern entrance to Crèvecœur, three regiments of cavalry, in process of formation, with six batteries of artillery; 7 P. M., landed at Poix."

Nearly all the aviators were kept busy. Latham took with him Lieut. Jost to make general observations. Lieut. Bréguet sailed over Grandvilliers and Briot with Capt. Hugoni, passing over the "Zodiac," then continued on to Thiculoy, Prévilliers, and back to Poix *via* Hetomesnil. A second trip led Bréguet along the Val d'Enfer. Lieut. Mailfert first started with Capt. Hugoni, then made alone a trip in behalf of the Reds. For the Blue Army, Capt. Letteux and Comte de Lambert made observations over and around Formerie, while at headquarters the Adjutant Caille and Comte de Robillard, having on board respectively Commandant Clolus and Capt. Marie, made excursions to the advance lines.

One of the features of the day was the voyage of the "Clément-Bayard II.," which left Issy at 1:15 P. M. for Grandvilliers, carrying a crew of seven and covering the twenty miles to the capital in two hours and a quarter at an average elevation of 400 meters.

The two Lebaudy airships, "Colonel Renard" and "La Liberte," likewise acquitted themselves with credit by sailing, the former from Issy to Beauvais and back, and the latter to Grandvilliers.

The "Zodiac" crossed the valley separating Grandvilliers from Poix, piloted by the Comte de la Vaulx, and after reconnoitering the positions of the Third Corps, made a splendid landing.

At 5:15 P. M., after having made three ineffectual attempts, Lieut. de Caumont started and passed over the valley of the Seine into the valley of Darnétal, through which he arrived at Forges-les-Eaux, thence reaching Buchy at about 30 kilometers from Rouen.

Saturday, September 17th.—Dirigibles and aero-

planes took a day of much-needed rest after the hard work they went through the day before and availed of the opportunity to prepare for such additional demands as might be made upon them for the last day.

Sunday, September 18th.—The close of these brilliant Picardy maneuvers was heralded by a bright sun, dispelling mist, and a calm atmosphere, permitting of all desired evolutions. At one time as many as eight aeroplanes and the four dirigible balloons were seen sailing over the battlefields.

The "Clément-Bayard II." rose at 7:15 A. M., piloted by Lieut. Tixier and carrying Commandant Ferrié, chief of the wireless telegraph post at the Eiffel Tower, with which was held constant communication. It took a northwesterly course, passing over Puteaux, Canbovoie, Bezons, Beauvais, and at 11:30 landed at Briot-Aviation.

The "Colonel Renard" left Issy-les-Moulineaux at 8 A. M., piloted by Capts. Delassus and Bienvenu, and followed the same course as the "Clément-Bayard II.," reaching Briot-Aviation at 12:10 P. M.

The "Zodiac" was ordered to return to Paris. It left Grandvilliers at about 1 P. M. in charge of the Comte de la Vaulx, and landed at Issy at 4:30, having crossed the 130 kilometers in 3½ hours against a head wind.

The "Liberté" had meanwhile risen majestically at a height of exceeding 150 meters and with a headwind tacked toward the plateau of Morvilliers, where the foreign officials had assembled. Shortly after its reaching that point the wind fell, and in the sky appeared the smaller "Zodiac," followed by the Bréguet biplane and the Blériot monoplanes of Lieut. Bellanger and Capt. Letteux. Both the latter sailed together at a height of over 350 meters and were soon joined by the Farman biplane of Major Ménard, while in the distance appeared four other biplanes and another monoplane piloted by the Comte de Robillard and Commandant Cloius. There would have been a good chance to try, especially against the dirigibles, the auto-gun, which had been stationed on the Morvilliers road to Ioneuse, but it was not ready for the purpose, and all aviators were allowed to pass safely in all directions and at different heights.

Monday, September 19th.—The "Clément-Bayard II." was nearly destroyed. At 6:30 A. M. the three dirigibles, "Clément-Bayard II.," "La Liberté," and "Colonel Renard" left in company the hangars of Grandvilliers to go to Paris. The "Clément-Bayard II.," having on board Lieuts. Tixier and Beaudry as pilots, Col. Hirschauer, Capt. Riéndt, and Engineer Anselme, was instructed to make especial observations along the route of the movements of all military bodies and of all trains running between Briot and Paris, all of which Capt. Riéndt afterward embodied in a report to the Minister of War. The "Clément-Bayard II." reached Issy at 11:15 A. M., and at 4:14 P. M. started again, with Mr. Clément and six others, in order to reach Lamotte-Breuil, near Pierrefonds. The weather was perfectly lovely at the start, but by the time the dirigible reached Chantilly, it struck such a very violent storm that it was rapidly carried ahead of the Northern express train, and while over the Layle forest the lightning played so fiercely against the steel sides and against the wireless apparatus as to seriously endanger the safety of all concerned until a landing was effected in the plain of Breuil.

The "Zodiac" left to-day for St. Cyr, there to be disinflated until further required.

From the above, it will be seen that a new era in war has truly been opened.

It cannot be denied that the experimental stage of military airmanship has successfully been passed, nor can it be questioned, as the French Minister of War expressed it, that the aeroplane, hitherto admitted a marvelous agency for transmitting orders, has now proved its value as a singularly formidable engine of exploration.

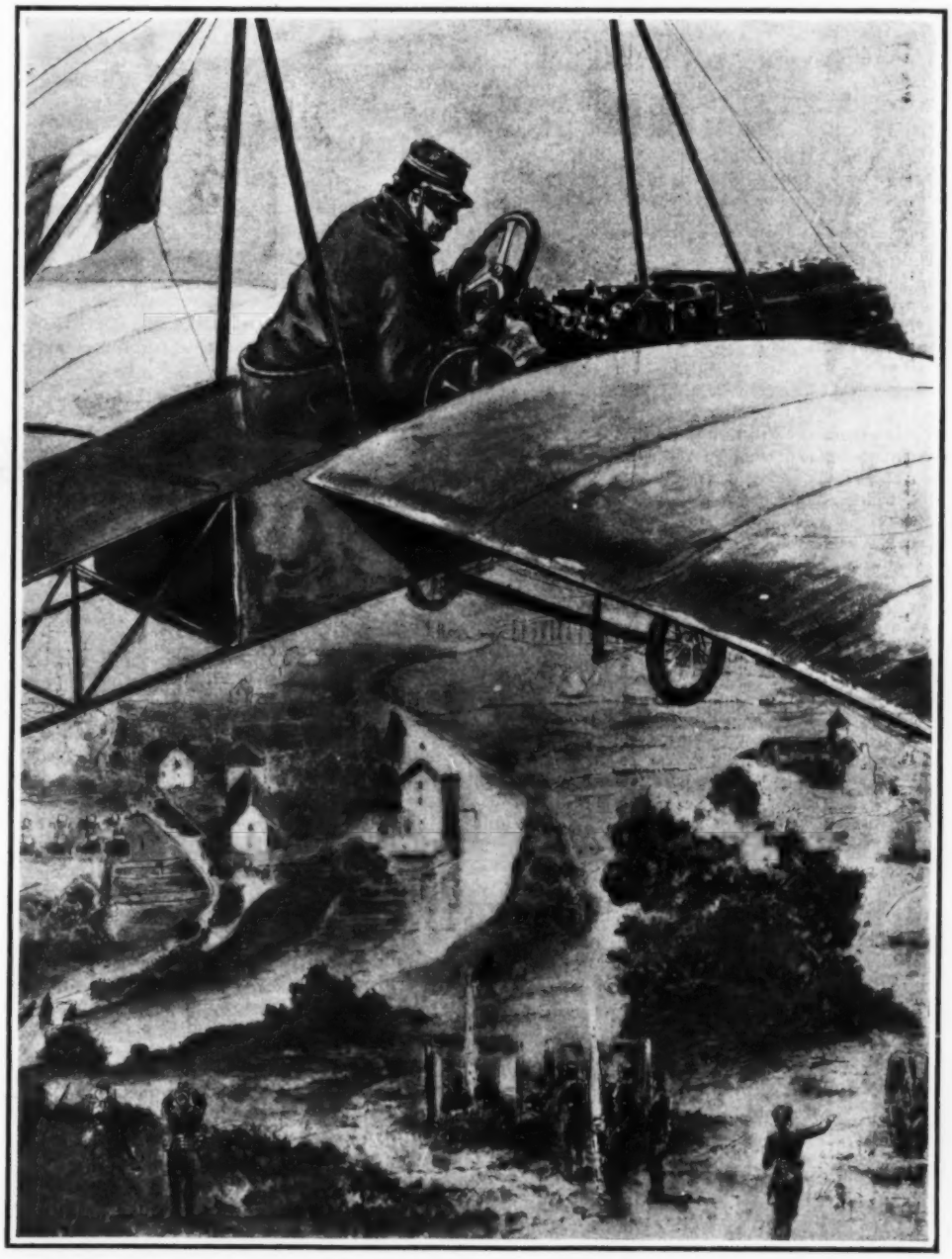
For the aeroplane, which has now been accepted by French military authorities as "the fourth arm," large additional orders have been sent in. And, with the 20 Farman biplanes and the 10 Blériot monoplane racers to be delivered in three months' time, the French army will, before 1911, have an aeroplane force of 60 machines and naturally, besides, all the needed trained army airmen to manage them. The new machines, it is said, are to have a radius of 250 kilometers, to each have a reserve motor and to be able to carry three men equipped and armed for war with an additional weight capacity of about fifty pounds.

In addition, military flying schools have been established already at the Châlons camp, at Satory, and at Vincennes, to be followed immediately by others at Rheims, Clermont-Ferrand, Pontarlier, and the Le Courtine camp. To each of the new stations will be given 12 machines, on which 20 airmen will be schooled by military instructors; and, as soon as these stations prove to be in good working order, new schools will be opened, doubtless for each army corps, one of the most important being that intended for the Nineteenth (Algerian) Corps, since upon the latter will devolve the projected attempt of linking up Algeria with Timbuctoo, across the Sahara, by air. In addition to the army stations above named, there is to be one established at Toulon, under control of the Minister of Marine, who is likely ere long to decide upon additional ones at different coast centers.

It is noticed that the bomb-dropping which had so long been talked of, but which is not very highly valued in prominent circles, has been totally ignored in the instruction at army flying schools, as has also to a great extent, at least for the present, the question of gunnery against flying aircraft apparatus. Naturally, the experiments made by the United States and other naval departments to test the destructive power of explosives dropped upon decks of battleships will be closely followed. The shooting at aircraft experiments on the Cornish coast have been fully commented on, but the results were not satisfactory. As is known, a string of five man-lifting kites, excluding the pilot kite, was sent up from the deck of H. M. scoutship "Adventure" in Whitsand Bay. From each kite two small balloons were suspended and constituted the targets. The kites flew at an altitude of 1,300 to 2,000 feet, the balloons floating some 200 feet below, and the string was carried by the "Adventure" steaming at 18 knots. Many shots were fired at the targets by the Royal Garrison Artillery and by the Royal Field Artillery, but only the latter's howitzers were able to make occasional hits, owing, it is said, to the mist most of the time prevailing.

Of the newest guns constructed by the Messrs. Krupp of Essen, for use against aircraft, three types have been made, of 6.5, 7.5, and 10.5 centimeters. All fire shells that explode immediately they touch the target, and they reach to a height of 20,000 feet on land, while the guns designed for use at sea reach an altitude of 35,000 feet at an angle of 75 deg.

In the Picardy maneuvers were cannon that could be fired at all angles and capable of firing 250 shots a minute, which were mounted upon motor-cars built for very high speed to follow and destroy airships, but as we have seen, they were not tested.



The Graphic.

THE NEW SPY OF THE AIR.

ON ZOOLOGICAL NOMENCLATURE.

ONE of the most valuable features of international congresses is the creation of international committees for the purpose of discussing and reporting upon questions of dispute among their members, many of whom are of differing nationalities. This is conspicuously the case with zoologists, where questions involving the proper use of nomenclature are so very important. The development of the work of the International Commission on Zoological Nomenclature is a striking evidence of this fact.

Its history is of interest. An International Commission on Zoological Nomenclature was appointed in 1895 by the Third International Zoological Congress, held at Leyden, Holland. There were originally five members. The commission was directed to study the various codes of nomenclature and to report upon the same to a later congress.

At the Fourth (Cambridge, England) Congress, 1898, the commission was made a permanent body, and increased to fifteen members, who later (at the Berne Congress, 1904) were divided into three classes of five commissioners each, each class to serve nine years.

During the interval between the congresses, the commission has been in correspondence; it has held one meeting (1897) between congresses, and regular meetings during the triennial congresses. As a result of its labors, the original Paris-Moscow (1889, 1892, the Blanchard) code was taken as the basis, and with certain amendments was adopted (Berlin Congress, 1901) by the International Congress. Amendments were presented by the commission to the Boston Congress (1907) and were adopted.

The Berlin meeting (1901) adopted a rule that no amendment to the code should thereafter be presented to any congress for vote unless said amendment was

in the hands of the commission at least one year prior to the meeting of the congress to which it was proposed to present the amendment.

Prior to the Boston Congress a desire had developed among zoologists that the commission should serve as a court for the interpretation of the code, and in accordance therewith the commission presented to the Boston Congress five opinions which were ratified by the congress.

Since the Boston meeting, a number of questions on nomenclature have been submitted to the commission for opinion. Owing to the amount of time consumed in communicating with the fifteen commissioners, it was impossible to act promptly upon these cases, but in the winter of 1909-1910 the Smithsonian Institution gave a grant to provide for the clerical work, and since that time it has been possible to render the opinions more promptly.

The commission has no legislative power. Its powers are restricted to studying questions of nomenclature, to reporting upon such questions to the International Congress, and to rendering opinions upon cases submitted to it.

The Smithsonian Institution has now undertaken the publication of these opinions up to a certain point. Publication No. 1938 entitled "Opinions Rendered by the International Commission on Zoological Nomenclature," has just been issued by the Smithsonian Institution and gives the first twenty-five opinions prepared by this commission.

The following is the method to be adopted in submitting cases for opinion, and zoologists will aid the commission in its work if they will bear in mind the following points:

(1) The commission does not undertake to act as a bibliographic or nomenclatural bureau, but rather as an adviser in connection with the more difficult and disputed cases of nomenclature.

(2) All cases submitted should be accompanied by (a) a concise statement of the point at issue; (b) the full arguments on both sides, in case a disputed point is involved, and (c) complete and exact bibliographic references to every book or article bearing on the point at issue.

The more complete the data when the case is submitted, the more promptly the latter can be acted upon.

(3) Of necessity, cases submitted with incomplete bibliographic references can not be studied, and must be returned by the commission to the sender.

(4) Cases upon which an opinion is desired may be sent to any member of the commission, but—

(5) In order that the work of the commission may be confined as much as possible to the more difficult and the disputed cases, it is urged that zoologists study the code and settle for themselves as many cases as possible.

A 1,000-MILE WIRELESS STATION.—III.

HOW TO CONSTRUCT THE RECEIVING STATION.

BY EDWARD H. GUILFORD.

Continued from Supplement No. 1814, Page 230.

THE operating room, or room in which the instruments are kept, should be such that it is free from all noise and vibration. The attic is in most cases the best, for a room in that part of the house is usually remote from the living-rooms of a house, where is apt to occur the most noise. The ideal arrangement is to have a separate shanty where all of the above conditions may be fulfilled. Fig. 9 shows the plan and elevation of such a room. It will be noticed that a bench extends across two opposite sides of the room, with long windows above them, and a door at one end of the shanty. Each bench should be about 30 inches high and 36 inches broad, care being taken that it is constructed in such a manner that it will be thoroughly rigid. For the material, pine wood is generally used, although if one desires it may be improved by making the top or even the whole bench of some hard wood, such as oak. One of these benches is to be used as a work bench, while on the other will be placed the instruments. A set of drawers should be built beneath one end of the work bench, for they will be handy to store tools, magazines, old instruments, etc., in. Two chairs, a cot, and some form of heating device go to make up the rest of the furnishings of the room.

By referring to Fig. 10 a general idea of the arrangement of the transmitting and receiving instruments may be obtained. It will be noticed that the transmitting instruments are at one end of the bench, while the receiving instruments are at the other end. The spark gap should be as far away from the detector as possible, since the detector shows a great tendency to "blow out," or become less sensitive when a spark of any great power occurs nearby. Referring to the diagram again (Fig. 10), *SOS* is the transmitting oscillation transformer, *H* is the helix, *SG* is the spark gap,

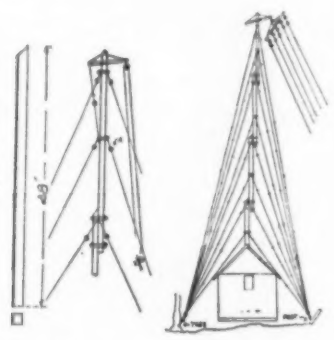


FIG. 1. FIG. 3.

AS is the aerial switch, *C* is the variable condenser, *T* is the tuning coil, *F* is a double throw triple knife switch (used to change over from tuning coil to oscillation transformer), *P* is the potentiometer; *OSR* is the receiving oscillation transformer, *K* is a switch to change from tuning coil to oscillation transformer, *D* is the detector and *BB* are the telephone blocks, by means of which one or more pairs of telephones may be switched into the circuit. The transformer, condensers and impedance coil, not shown in the plan, are placed on a shelf underneath the rest of transmitting instruments.

* Electrician and Mechanic.

The electric light company sometimes requires that where the electric light current is to be used for the transmission of wireless signals, certain protective devices should be installed in the primary circuit to protect the wattmeter. These requirements vary with

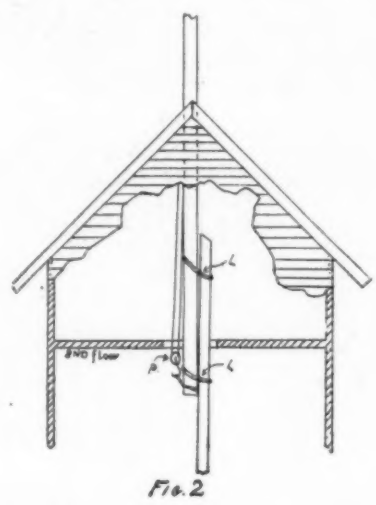


FIG. 2.

the locality, and the reader should consult the local electric light company in regard to them.

In wiring the transmitting instruments the best results are only obtained by thoroughly insulating all wires by means of porcelain cleats. Use No. 14 rubber covered wire in wiring the primary circuit, and No. 10 rubber covered wire in the secondary circuit. In order that the wiring of the station may comply with the Underwriter's laws, all wiring must be inspected by one of their inspectors, who will come upon receipt of a notice to that effect.

Regarding the protection of the aerial wires, it is usually required by the Board of Fire Underwriters that the antenna when not in use should be connected by means of a 100 ampere switch to a No. 4 B. & S. gage insulated copper wire which is connected to the water pipes or some other ground *outside of the house*. The rules require that this wiring also should be inspected.

The ground wire which goes to the instruments should be a No. 10 copper wire, and it may be either insulated or uninsulated. It should be soldered to the water pipes in any part of the house, but never to the gas pipes. If there are no water pipes near the house, as would be the case were the shanty suggested in this article used, a suitable ground may be had by burying 100 to 150 square feet of sheet copper or zinc in the ground at such a depth that the surrounding earth will always be moist. If the wireless station is near a body of water, ground may be obtained by sinking a large area of ordinary chicken netting, say 200 square feet, at the bottom of the water.

A good antenna should cover a large surface, and it should also extend some distance above the surface of the ground. The best antenna is perhaps the umbrella type, but since every one cannot, on account of limited space or some other cause, have such an aerial, I will describe the most common types of aerials used and a selection from them may be made which will be governed by local conditions.

1. The vertical aerial, Fig. 8, consists of 6 to 12 wires hung vertically, or almost so, from the top of a mast which should be at least 60 feet high. This type of antenna is very good for both sending and receiving and is undirectional, or practically so, messages coming in equally well from all directions. The wire to the instruments should be connected at the bottom of the aerial wires. The wires at the upper end of the aerial may be either connected together or left free. The instruments should be as near the base of the mast as possible.

2. The umbrella type. In this type of antenna, Fig. 7, a number of wires radiate in all directions from the top of the aerial mast. They run to within 8 to 10 feet of the ground at about a 45 deg. angle. From 12 to 24 or even more wires may be used, depending upon the height of the mast. They should all be connected together at both top and bottom, the wire to the instruments being connected to the bottom. This type of aerial is absolutely undirectional, and is exceptionally good for transmitting, since a very large surface is exposed to the air. The mast should be at least 60 feet high.

3. The flat top aerial. This is the type of antenna which is used at sea, and also by a great many amateurs. (See Fig. 5.) In its most common form it is horizontal, or nearly so, and is suspended between two poles, or trees, or even the roofs of two houses. From 4 to 10 wires are used, and to secure the best results they should be at least 75 to 100 feet long and at least

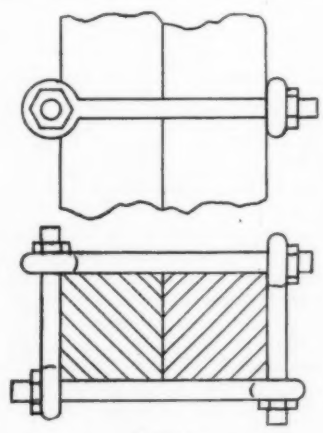


FIG. 4.

40 feet above ground. This type of antenna is extremely directional if the wire to the instruments is connected to either end, but by connecting it to the middle of the antenna the directional effect may be destroyed in some cases. The Marconi Company uses this type of antenna in its transatlantic work, the aerial being purposely made directional. The end of the antenna to which the wire to the instruments is connected points in the direction in which the signals are best received.

In making any form of aerial these points should be observed: Always insulate each end of each wire from the spreader which supports it. This may

done by using an insulator made of 4 or 5 spool insulators tied in a string, although the strain insulators which have recently come upon the market are to be recommended. Each wire should be separated a distance of at least 2 feet from its neighbor. In making connections all joints should be soldered.

The mast will next concern our attention. It is made in 4 sections of well seasoned spruce, each section being 28 feet long and of square cross-section. The top section is 3 inches square at the bottom, tapering to 2 inches at the top; the next lower section is 3 inches square throughout its length, the section next to the bottom is 4 inches square at the bottom tapering to 3 inches at the top, and the bottom section is 4 inches square throughout its length. Each section should be carefully planed, and painted with a double coat of paint. The top of each section is beveled (see Fig. 1), so that it will shed rain.

The guy wires are No. 10 galvanized iron wire, and they are broken up every 25 feet or so, with 2-inch spool insulators, in order to prevent absorption of energy while sending. The lengths of these guy wires may be determined by using the following simple formula:

$$L = \sqrt{HV}$$

where L is the required length, V is the height above ground of the point on the pole to which is to be fastened, and H is the horizontal distance from the bottom of the pole to the point at which the guy wire is to be anchored. The cross arm at the top of the mast (Fig. 1) is a piece of spruce 4 inches square and 3 feet long. Its purpose is to hold the top of the aerial away from the uppermost guys.

FIG. 5

The erection of the mast is not very difficult, but it must be done with extreme caution. The following directions should be carefully memorized before attempting to do any work. I have described a method of erecting it through the roof of a barn, but there is no reason why it could not be as easily erected at the end of the barn. If the reader has no barn at his command he can, by taxing his ingenuity, devise some arrangement which will take the place of such a building, for I have taken up all the essential points in its erection.

To begin with, a hole 9 inches square should be sawed in the roof of the barn along the ridge pole and in such a position that one side of the hole will come next to the junction of two rafters. This will serve to brace the pole on its way up. A plumb-bob should then be dropped and holes sawed in both the second and first floors of the barn. Then directly underneath the bottom hole a pit should be dug of such a depth that when a section of the mast is placed down through the holes and the pit the top of it will not be more than 6 or 7 feet above the second floor of the barn. It should be noticed that the sections of the mast may be placed side by side in these holes.

A hoisting tackle, which may be rented of the local painter, is used to hoist the mast. It consists of two pulley blocks, one of which has two pulleys and the other three, and about 120 feet of ¾ inch hemp rope. The top of this tackle is fastened to a piece of 4-inch by 4-inch wood laid across the hole in the roof of the barn.

The top section of the pole, which will be called No. 1, and the section beneath it, No. 2, may now be dropped down through the holes. Next fasten the tackle to section No. 1 (see Fig. 2) and after placing two loops of wire around both sections (*LL*, Fig. 2), proceed to hoist the section until its butt is within 3 feet of the top of section No. 2. The loops of wire are used to keep the upper section in a vertical position, and they should be loose enough to allow the upper

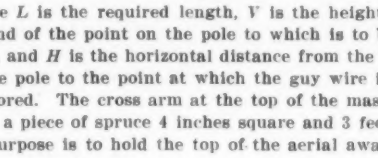


FIG. 6

section to slip through them freely. They should be temporarily fastened to the lower section. The two sections should now be bolted together by the method shown in Fig. 4, two sets of ¾-inch eye bolts being used (see Fig. 1). As the pole is being raised a man should be stationed on the roof to fasten on the guy wires as the points to which they are attached (have previously been marked) come up through the roof. There are 4 guys to each point on the pole and they are attached to the bolts at the joints of the pole and to a set of similar bolts in the middle of each section, by means of an insulator and a short piece of wire. (See Fig. 1, the black dots represent the insulators.) To prevent the wires from tangling up, they should be laid out along the ground at the foot of the pole. It is perhaps needless to say that the cross arm, Fig. 1, should be fastened in place by lashing it with wire, before the section is hoisted; the pulley with 200 feet of rope also being lashed on at this time.

Section No. 3 is now dropped down through the holes and the same procedure as before is gone through. The tackle is fastened to the bottom of sec-

FIG. 7

tion No. 2, that section is loosely looped to section No. 3, and the pole is hoisted until the ends of the sections are within 3 feet of each other, and are then bolted together. In all cases ¾-inch eye bolts should be used. About this time it will be found necessary to station four men on the ground, each one holding a guy from the top section, so that the pole may be prevented from buckling over. In order that they may keep the pole in control they should take a turn of the guy wire about some nearby tree or post, and as the pole slowly rises they must slack up on the wire by letting it slip through their grasp.

After the fourth and last section is bolted on, the pole is hoisted until its butt reaches the level of the second floor. A 2 inch plank, 4 feet long, is then placed underneath it. The bottom of the pole should now be permanently fastened in position by guying it to the four walls of the barn. All the guy wires fastened to the pole outside the barn may now be temporarily fastened, while preparations are being made to straighten the pole. Two plumb lines are now hung up at adjacent sides of the pole and about 50 feet away from the base. By sighting along these plumb lines and adjusting the guy wires the pole may be easily brought into a vertical position, the lower sections being straightened first. The guys are then permanently fastened to their anchorages, which are preferably trees. Twelve-inch posts, each having two 4-foot

FIG. 8

cross pieces bolted to their bottoms, are buried in the ground a distance of 6 feet or even more, especially if the soil is sandy, will serve in case no trees are near at hand. In either case the anchorages should be situated at the four corners of a square.

The aerial for use with a mast of this sort is the vertical type (No. 3). The wires, eight in number, should be stretched between two oak spreaders, each 14 feet long. These spreaders are of circular cross section, having 3 inch diameter in middle, and tapering to 2 inches at each end. The top of the aerial is hauled up by means of a pulley and rope, fastened to the yard arm, as seen in Fig. 1. The top spreader should not be hauled up tight against the yard arm, but should hang at least a foot below it, for when the rope with which the spreader is hauled up becomes soaked with rain, it shortens, and hence tends to pull the aerial up. If there is no slack the rope will either break or tear the pulley away from its fastenings.

In the remaining article I will give several wiring diagrams, including some of the standard systems. Methods of using and adjusting the various instruments will also be discussed.

(To be continued.)

By reason of the existing treaty on the subject, Russia has the privilege of laying down all new railways in Armenia and the region of Asia Minor lying along the southern coast of the Black Sea. It has long been a question of laying down a line of railway from the Black Sea port of Samsun in Trebizond in a southeasterly direction inland to the town of Sivas, on the Kizil-Irmak. As Russia is not disposed at the moment to carry on this work of railway construction in Asia Minor, an understanding has been come to with a French syndicate of financiers, who have secured the support of the French Government, for the purpose of laying down the projected railway. This railway will be about 290 miles in length, and it will traverse Turkey's richest region, so far as mineral wealth is concerned, and will form the main line of communication between the Black Sea and the high-lying plateaux of Armenia. A great feature of the negotiations has been that the French syndicate referred to, asked for no guarantees or subsidies of any kind from the Ottoman Government, and thus the Ottoman Government will be able to grant the concession without the consent of the Parliament. One-fifth portion of the undertaking has been reserved for exploitation by a Russian syndicate.

ALCOHOL FROM SULPHITE-CELLULOSE WASTE LYES

ACCORDING to an article by C. G. Schwalbe, published in the Zeitschrift f. ang. Chem., in 1891 Lindsey and Tollins made an investigation of a sulphite-cellulose

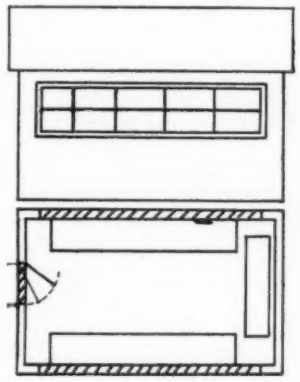


FIG. 9

waste lye, containing 9 to 10 per cent of dry solids, and found in it 1.2 per cent of fermentable sugar, the yield of alcohol being 58 to 67 liters per ton of cellulose. Recently, in Sweden, Wallin, at Forss, and Ekström, at Skutskär, have attempted to develop an industrial process on this basis. The two processes are identical in all essentials except that for the neutralization of the crude acid lyes, the former uses lime and the latter the waste causticization sludge from sulphite-cellulose mills. The lyes are first neutralized in large vats; they are then cooled, e. g., in towers, and are simultaneously aerated. It is claimed that the neutralization-sludge obtained in the filter-presses after this process, if used for the preparation of fresh lyes, contains sufficient calcium sulphite to effect a saving of 40 to 45 per cent of the sulphur required. In a mill producing 10 tons of cellulose per 24 hours the volume of the lyes to be treated amounts to about 100 cubic meters per day, and the quantity of neutralization-sludge may be taken at about 1½ tons dry or 3 tons moist. A yeast nutrient, malt extract or dead yeast, is added to the neutralized, cooled, and aerated liquid, which is transferred to the fermentation tuns. These must be large enough to allow of a storage of at least three days' duration. After fermentation and separation of the yeast, the lye is distilled in a continuous still. The column apparatus designed by Kubierschky is particularly suitable for the distillation of sulphite lyes. The alcohol in these is in an extremely dilute condition and the consumption of steam in their distillation is far

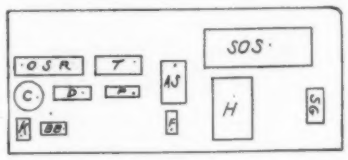


FIG 10

larger than in a molasses distillery. The alcohol obtained is already denatured; it contains considerable proportions of methyl alcohol, pre-existing in the unfermented lyes, also of aldehydes, furfural and probably acetone; it appears to be practically free from terpenes. The process is being worked on a considerable scale at Skutskär; the average yield of alcohol may be taken as about 60 liters per ton of cellulose, and the present out-turn is 50,980 liters monthly. It is stated that, under Swedish conditions, the treatment shows a profit, but the author points out that it offers no solution of the problem of the disposal of the waste lyes; on the contrary, it may even happen that owing to the presence of dead yeast, etc., in the spent wash, the nuisance may be aggravated rather than abated.

THE RAILWAYS OF THE HOLY LAND.

A MODERN INNOVATION IN AN ANCIENT LAND.

BY HAROLD J. SHEPSTONE.

Gradually the Holy Land is being covered with a network of railroads, and to-day the screech of the locomotive may be heard not only in Jerusalem, but on the shores of the Sea of Galilee, in Nazareth, and in many other places associated with Biblical history.

ZIZEH, A STATION OF THE DAMASCUS AND MECCA RAILWAY NEAR MAAN, THE ONE FROM WHICH THE ROCK-HEWN CITY OF PETRA IS REACHED.

The first railroad to be opened in this historic land was that which runs from the seaport of Jaffa to Jerusalem. The distance by rail is fifty-five miles, and the journey occupies three hours and forty minutes. Often it takes much longer, and not infrequently travelers are five or six hours upon the road. By a curious arrangement, the trains only carry the Turkish mails, besides passengers; and the foreign post offices in Jerusalem have to bring their mails from Jaffa by horse-drawn wagons. Except in the height of the tourist season, there is only one train a day, which leaves the seaport at 1:30 P. M.

As the steamers invariably arrive early in the morning, one is afforded an opportunity of seeing the city before proceeding to Jerusalem. Jaffa is at once picturesque and Oriental, with its clusters of palms and white flat-roofed houses. It is one of the oldest cities in the world, although some people ignore the tradition that it was founded by one of Noah's sons. It has been the chief port of Jerusalem since Solomon landed his materials there for building the Temple.

Leaving the city, the train plunges into the beautiful and extensive orange groves in the richly cultivated plain of Sharon. Soon the modern village of Yasur is seen on our left. It was here, according to tradition, that Samson caught three hundred foxes. The first stopping place of any importance is Lydda, the site of Lod, which was built fourteen hundred years before Christ. Thirteen and a half miles from the terminus Ramleh is reached, the journey so far occupying an hour. It is the traditional site of Arimathea, mentioned by St. Matthew. In the town there is the old Crusaders' church, now used as a mosque. Crossing the carriage road, we detect away to the left, on the top of a mountain, Neby Samuel, the Mizpeh of the Old Testament. It was at this spot that all the Children of Israel, from Dan to Beersheba, were called together several times. Saul, the first King of Israel, was chosen at Mizpeh.

Our course now lies across the plain of Lejed, when we begin to ascend what is known as the "hill country" to Judea. We pass to the left of Beth Shemesh, where the Ark rested, and are soon at the station at Deir Aban. Another hour and a quarter brings us to Bittir. According to Jewish history, this was a place of great strength. It contained four hundred synagogues, each of which boasted four hundred teachers. Here the Jews made their last stand against the Romans. The siege lasted over three years, and when the place fell it is recorded that 800,000 persons were slain.

Progress is so slow that it requires only an ordinary amount of activity to jump out, pick the flowers along the line, and rejoin the train as it laboriously moves up the steep incline. American tourists are fond of performing this feat. Jerusalem does not come into view until the train is quite close to the city. The first objects to meet the eye are the Tower of David and the city walls. The total ascent during the trip of fifty-five miles from the sea is not less than 2,600 feet. The line was built by the French at a cost of a little over $3,000,000.

For many years this interesting railroad was the only one in the Holy Land. Now there are three others, comprising those from Beirut to Damascus, from Haifa round the Sea of Galilee to Damascus, and the Mecca or Hedjaz enterprise, which carries Mohammedan pilgrims from Damascus to Medina, the birthplace of Mohammed.

Beirut, on the Mediterranean, is by rail ninety-one miles from Damascus. The journey takes nine and a half hours. The railway is a narrow gage, and for climbing the mountainous portion (about twenty miles) a cogwheel and rack system is employed. Tourists making the journey invariably leave the train at El Mulakka, thirty-five miles from Beirut, and go by road to the ruins of Baalbek near by. This was once the most magnificent of Syrian cities, full of palaces, fountains, and beautiful monuments. Now it is famous only for its ruins, the most imposing of which are those of the Temple of the Sun. This railroad was also built by the French, and crossing as it does the Lebanon, passes through some really beautiful scenery.

The Haifa to Damascus line owes its inception to the Mecca railroad. When the latter work was put in hand, all materials for its construction had to be carried from Beirut to Damascus by the French railroad. The rates charged the Turkish government by this line were so high, however, that it was decided to build this side line, giving them a direct communication with a seaport. The gage is 4½ feet, and it was built by English engineers. As the track runs across the Province of Galilee and touches many places mentioned in the New Testament, it is naturally much patronized by tourists.

JERUSALEM STATION OF THE JAFFA AND JERUSALEM RAILWAY.

WATER TANKS ON THE DAMASCUS AND MECCA RAILWAY NEAR ZIZEH.

Skirting along the foot of Mount Carmel, sacred to the Prophet Elijah, the railroad runs to Afuleh, close to Nazareth. This is the first stopping place of any importance. Nazareth to-day is a flourishing town of 10,000 inhabitants, the majority of whom are native Christians. It was originally intended to continue the railroad round the western shores of the lake. If this had been done, Tiberias, Magdala, and Capernaum would have been connected with the Mediterranean by rail. The engineers, however, finally decided to run the iron road round the southern end of the lake. The track passes through Semakh, at the southern extremity of the Sea of Galilee, from which boats carry passengers across to Tiberias. From Semakh the line proceeds up the wild gorge of the Yarmuck, and thence to Daraa, where it joins the main line from Damascus.

The Hedjaz project claims to be the only railroad built for the purpose of carrying pilgrims. Indeed, it is known as "The Railroad of the Pilgrims." Starting from Damascus, it runs almost due south through wild and sterile country for more than 820 miles to Medina. The rails used are of steel, and were imported from the United States, as were also the iron ties. The rolling stock came from Belgium and Germany, the first-named country supplying the freight cars, and the latter the passenger cars. It was the deposed Sultan of Turkey who suggested the construction of this railroad, and the Turkish government handed over to the commission appointed to carry out the proposal, 17,000,000 unused postage stamps. These were sold by auction, in order to help finance the scheme. In passing it may be noted that the gage is one of 1.05 meters (3.445 feet).

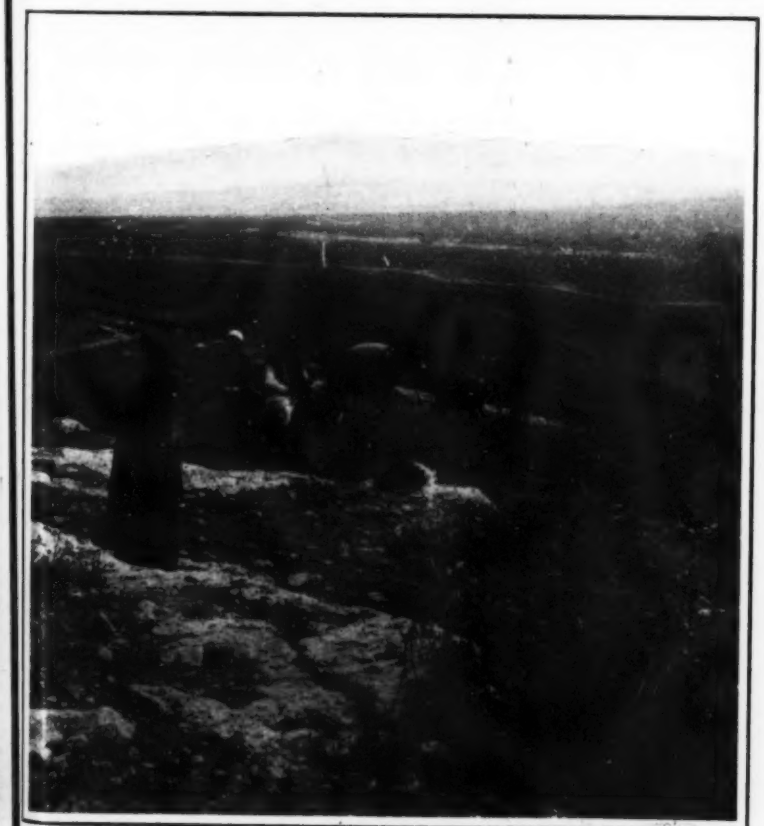
A trip over this railroad is an interesting experience. On leaving Damascus, the route enters what is known

A TRAIN COMING FROM THE SOUTH ON THE DAMASCUS AND MECCA RAILWAY.

DAMASCUS AND MECCA RAILWAY. TURKISH SOLDIERS WHO DO THE WORK OF CONSTRUCTION ALIGHTING FROM A BOX CAR OF A TRAIN.

AMMAN STATION ON THE DAMASCUS AND MECCA RAILWAY.

TRAIN AT RAYAK IN THE PLAIN OF THE BAACA BETWEEN THE LEBANON AND ANTI LEBANON ON THE BEIRUT AND DAMASCUS RAILWAY (NARROW GAGE) THE JUNCTION OF THE NEW RAILWAY (BROAD GAGE) RUNNING NORTH TO BAALBEK.



THE PLAIN OF ESDRAELON ALONG WHOSE HISTORIC LENGTH RUNS THE NEW HAIFA AND DAMASCUS RAILWAY.

VIEW FROM MOUNT CARMEL OF HAIFA, THE STARTING POINT OF THE NEW HAIFA AND DAMASCUS RAILWAY.

THE RAILWAYS OF THE HOLY LAND.

as the Hauran. This is a vast plateau almost entirely devoted to the raising of wheat and barley, both of excellent quality. On the west is the snow-capped mountain of Hermon. The first station of any importance is Daraa. Here a large repair shop has been built for repairing disabled locomotives. The station also boasts of its restaurant, where good meals may be obtained. There is also a post office and an international telegraph office, where messages can be sent in any European language as well as in Arabic and Turkish.

At Daraa, of course, the line is joined by that coming up from Haifa. From this spot the Mecca railroad gradually ascends the undulating slopes of a plateau as far as Zerka, where it drops into a deep valley, and climbs out again by a winding ascent on to another small fertile belt. As the line proceeds southward, signs of civilization become fewer and fewer, and the sense of wild desolation more pronounced. Purusing a course roughly parallel to the Jordan, and almost identical with the old caravan route, the railroad traverses a country which is full of history and romance to the religious mind—as much to the Christian as to the Mohammedan. Decayed ruins of a past civilization and silent monuments of a long-departed prosperity are visible on all sides.

At a point almost abreast of the Dead Sea the line enters a barren waste. A foot traveler passing through this region must be astonished at encountering the steel rails and telegraph poles which mean easy communication with distant but more hospitable districts. The interminable level of the sand is broken only on the western horizon, where the mountains of Moab raise their peaks dimly into the heated air. For a considerable distance the going is easy enough from the engineering point of view. The valleys are wide and contain no steep grades; the engineer could pick his path and lay his iron road in such a manner as to minimize the work to be exacted from the locomotives. But in one respect the country is difficult; it is practically waterless. During construction every drop of water used by the army of workmen had to be conveyed by train from the nearest well—in some cases many miles away—and stored in carefully guarded tanks.

A journey of some 285 miles from Damascus, and Mahan or Maan el Hagj is reached. From this point about eight hours' horseback ride to the west brings one to the unique and fascinating ruins of Petra, and by means of the iron road the tourist of ordinary means is thus able to visit these hitherto inaccessible ruins. Mahan itself is now quite an important place on account of its hospital, hotel, repair shops, and other buildings, many of them substantially built of stone. The Turkish government has now established a garrison here. It is believed by some that in time to come Mahan will blossom forth as a health resort, since the air is very invigorating, despite frequent dust storms.

Southward of Mahan the line traverses high ground more desolate, if possible, than the country already crossed—certainly more rugged. So the journey continues until El Ula is reached, 609 miles from Damascus and 210 from Medina. In some respects this is the most important station on the railroad. It is a little town of some 4,000 inhabitants, buried in the heart of the desert. It contains five hundred houses, and boasts copious springs and a thousand acres planted with date palms and cereals. The station, somewhat imposing and extensive, is the last depot north of Medina, and close to it are repair shops, engine sheds, and houses for the railroad staff. Beyond El Ula none but Mohammedans may go! Even the engineer-in-chief, who is a German, had to relegate to a Mohammedan assistant the carrying of the rails into Medina.

The railroad was mooted by the Sultan in 1900, and completed as far as Medina in 1908. It has been principally built by Turkish soldiers. Considering the immense physical difficulties to be overcome, this means the achievement of a remarkable engineering feat. Practically an unknown country had to be traversed, and all materials, stores, and provisions for the workmen had to be brought over the line from the seaboard. The road is certainly well and cheaply laid. The total cost for the Damascus and Haifa to Medina portion was only $15,000,000, or about $150,000 per mile. Now the Turkish government has declared its intention of carrying the rails into the holy city of Mecca itself. This will be no easy feat, as it means the laying of a track across the desert. When this project is completed, and the Bagdad railroad has progressed another 200 miles, and the Bosphorus has been spanned by a bridge, Mecca will be in direct communication with Constantinople. The illustrations are from photographs made by the American colony, Jerusalem.

HOW WOOD IS ARTIFICIALLY AGED.

THE COLORATION OF WOOD BY GASES AND FUMES.

BY H. WISLICENUS

THE current methods of preparing wood for the manufacture of furniture and similar articles are entirely superficial. The results are well known; the appearance of varnished, painted and stained articles which have been chipped, scratched or abraded, is anything but beautiful. To furniture and buildings constructed of naturally beautiful and unprepared wood, on the contrary, age brings a new beauty, and the indications of long use appear merely as evidences of durability and excellence. These fine old pieces are prized by the art historian and collector, and they often possess great artistic value, which is not disputed by any connoisseur, even though the particular style of the article may not agree with his individual taste or fit his peculiar surroundings. No such genuine artistic value can be conferred on wood by any of the superficial methods now employed. It is true that an artistic designer can produce striking and beautiful effects with bright stains and pigments, but in this process the wood itself loses in significance. When the object is to give an attractive appearance, temporarily, at least, to wood of inferior quality, such superficial staining, and covering with opaque pigments, have their usefulness and value.

Valuable objects of wood, however, are made to last for decades and even for centuries, and they are required to preserve their beauty longer than textile fabrics. Few of the current methods of treatment, and not one which employs synthetic dyes, can satisfy these demands, although there are many synthetic colors which are more permanent than the best of the old vegetable dye-stuffs. The wood is penetrated most deeply by colors dissolved in alcohol, but these colors are not the most permanent. Water colors penetrate only a small fraction of a millimeter into wood cut parallel to the grain, and the effect of turpentine and wax colors is still more superficial.

In order to stain the wood through its entire mass, it would be necessary to use great force and the elaborate apparatus which is required for the impregnation of wood with tar and other preservatives. Some such method has been employed in Austria, but not with complete success, for the process has a fundamental defect in addition to its great technical difficulty. To produce the proper effect it is necessary to impregnate the wood with the color before it is cut up, and consequently labor and costly dye-stuffs are wasted on sawdust, shavings and other refuse.

Wood impregnated with tar acquires a brown tint which is often very pleasing, but this method of coloring would not be suitable for articles of furniture, because the coloring matter of tar is not a true dye and possesses offensive odor. Treatment with the fumes of tar is unsatisfactory for the same reason. The so-called vapor is really a mist which does not penetrate wood any better than the liquid tar.

True vapors and gases, on the contrary, penetrate quickly into the innermost parts of the wood. For the coloration of wood in practice, only two such substances have been employed: superheated steam and ammonia. The latter gas produces various colors by its action upon substances contained in the wood, or intentionally added. The aqueous solution of ammonia has also been employed, but with less success. The coloration of wood by gases and fumes presents the following radical differences from the ordinary methods of dyeing and staining:

(1) In the coloration of wood by gases, dye-stuffs are not, as a rule, employed, and only small quantities of the gas or vapor are required to color the wood throughout. (2) In this method, therefore, the wood is not dyed or stained in the strict sense of the word, but is rather discolored by chemical change. (3) These chemical changes which, though conspicuous, are slight, take place in those unstable ingredients of the wood and sap which are removed in the process of cellulose manufacture for the very reason that they are so easily decomposed. They consist chiefly of substances of the tannin group, sugar, gum and other carbohydrates. Alkalies, ammonia and superheated steam darken all of these substances by partially decomposing them and forming the so-called "humin" bodies, which are brown in color. (4) Although gases and fumes possess the advantage of even and rapid penetration, they do not produce useful colorations without the aid of other influences, such as high temperature, light, and moisture, singly or in combination. The oxygen of the air promotes the action of ammonia and, conversely, ammonia accelerates oxidation or slow combustion. (5) The colors produced by the action of gases, especially ammonia, are dull and soft. This is no disadvantage, but rather the chief merit of this method, as these subdued colors have no startling or sensational effect, but give the impression of age and permanence. The production of such venerable hues throughout the mass of sawn wood is, therefore, the especial object of the treatment with gases and fumes. The pendulum of fashion has lately swung away from bright, artificial colors toward the employment of unstained wood, covered only with transparent glazes. This is an advantage in so far as it brings out the quality of the wood, but wood of the rarer sorts and beautiful specimens of wood of commoner sorts are very expensive.

Uncolored wood presents the further disadvantage that, although it may be partially protected from the effect of air and moisture by varnish or wax, both the wood and the varnish are affected by light and gradually discolored. A striking impression of genuineness and permanence is produced by the coloration which has been slowly acquired by the unpainted and unstained furniture and wood work of old farm-houses. Such ageing of wood requires too much time and we are therefore led to endeavor to accelerate the natural process. The most effective method of doing this consists in the coloration of the whole mass of the wood by the action of gases and fumes, in connection with air and moisture.

Let us now examine, in detail, the action of gases upon wood.

(A) *The natural discoloration of wood exposed to the air.* All wood becomes discolored in the air and the action penetrates throughout the mass, though at an exceedingly slow rate. Often the surface soon shows a marked change, which is always due to the action of oxygen or ozone, in combination with light, heat and moisture, upon the less stable ingredients of the wood or sap. Dust, especially if it contains iron and fungi and bacteria, may also contribute to this coloration. The effect of light is purely superficial. The yellowing of wood pulp paper when exposed to light is well known. The effect appears to be chiefly due to the ultra-violet rays. We find always two color changes, occurring simultaneously or successively, a very slow coloration of the entire mass and a comparatively rapid and striking change in the color of the surface, which may become yellow, brown or gray. Old wooden houses in the higher Alps have acquired a brown color of rare beauty. These inimitable tints are found only at great elevations and especially amid snow and glaciers, where the intensity of the sun's rays and of the ultra-violet rays in particular is little weakened by atmospheric absorption. Wiesner asserts that especially beautiful colors are found near bodies of water and in damp forest valleys, but this luminous red-brown tint does not occur in similar localities in the lowlands. The writer has made certain observations which give some explanation of this remarkable phenomenon.

The wood is always gray on the weather side of the house, which is frequently exposed to rain and snow. The sunny side is more or less brown, according to age. In some houses hundreds of years old, the color is so dark in spots that it appears almost black in diffused daylight. The projecting ends of the floor beams are found actually carbonized or charred, in very old houses. A few years' exposure produces a light brown color, and still newer houses have a pale yellow tint. Two phenomena are found in all cases: a pure gray on the weather side and an entire removal of color above the stable doors and privy windows.

The boards exposed to the ammoniacal vapors of such places are as white as the whitewashed foundation walls. The brown coloration is evidently quite superficial and unstable, as it is easily and completely removed by the moist ammoniacal vapors. The bleached spot is surrounded by a dark ring, in which the color has either been accumulated or darkened by ammonia. Close examination of the bleached sur-

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faces shows that not only the coloring matter, but all of the lignin of the wood has been removed. The superficial layer is a snow-white felted mass of fibers of pure cellulose, and gives none of the reactions of lignin. All easily decomposable incrustations are also removed by the combined action of light, air, moisture and ammonia.

The most remarkable peculiarity of this natural browning of wood is the fact that it does not take place to anything like the same extent or beauty in the lowlands. As the traveler descends from the snow line he finds the beautiful luminous brown color gradually superseded by a gray. Wherever a bright brown color is found in wooden structures in the lowlands, it has been produced artificially by a coating of tar or other substance employed as a preservative against decay. Very probably the tannins and the ferrous salts of the sap, which are sensitive to light and air, play a part in this natural coloration. The question is well worth investigation.

When cut wood is exposed to the open air, but protected from rain, the superficial layer at first acquires a yellow color, but this is gradually changed into a gray, usually of unattractive appearance, which has nothing in common with the gray of old age which permeates the whole of the wood in the interior of old houses. According to Schramm this superficial gray color is caused by traces of iron in the wood, or in the dust of the air, in combination with ingredients of the sap, which becomes oxidized, producing a greenish or violet gray, and ultimately a "dirty" gray color. Like all iron stains, this gray can be quickly lightened or removed by oxalic acid. The same gray color can be produced artificially by applying iron salts to some kinds of wood. In the natural process it appears most rapidly on wooden fences, posts and structures in dusty streets or courts; but even amid green fields and dustless air, the weather side of an unpainted wooden building always turns gray in time. Although this gray color due to iron rapidly produces an appearance of age, and is perhaps more pleasing than new wood, it does not possess the artistic value and effect of the genuine gray of age which is found in the interior of old houses.

(*B*) *Artificial coloration of wood with gases and fumes.*

1. *Fuming with ammonia.* Hitherto this comparatively new process has been applied only to woods abounding in tannin, for the purpose of producing the pleasing grayish brown color, which is so highly prized in old oaken furniture. The best technical treatises give directions for this easy process of imitating old oak, and for some modern improvements by which a similar effect can be produced in wood destitute of tannin. Fuming with ammonia is applied to the completed article of furniture or other object, by exposing it for a day or two to the combined action of ammonia and air in an air-tight chamber, in which shallow vessels containing a concentrated solution of ammonia are placed. Or the ammonia may be evolved by heating a mixture of ammonium chloride (sal ammoniac) and slaked lime over a small alcohol lamp. A small quantity of ammonia, together with the oxygen of the air, produces a soft brown coloration in the wood, which penetrates to a depth in proportion to the time of treatment. The usual exposure of one or two days gives a far deeper coloration than can be produced with liquid stains, yet even two or three days' exposure seldom produces an effect deeper than one-eighth inch. The treatment for wood containing no tannin includes a preliminary application of a tanning liquid. As ordinary tanning agents do not penetrate deeply into the wood, the liquid employed is a five or ten per cent solution of pyrogallic acid, which is very easily oxidized and is deeply colored by ammonia and oxygen. But even this solution does not reach the interior of the wood and, consequently, characteristic advantage of fuming with ammonia is lost.

The same fundamental defect exists in Thimm's method, in which wood naturally free from tannin is steeped in solutions of metallic salts and then fumed with ammonia or sulphureted hydrogen, which produces variously colored metallic compounds in the fibers of the wood. By this method it is possible to attain a great variety of tints, but these are only superficial and could be produced as well by the use of ammonia solution or other liquids. Even for oak abounding in tannin, the employment of fuming with ammonia is so restricted by various causes that the process is seldom used, notwithstanding its simplicity. The quantity of tannin in oak varies in different trees and even from layer to layer of the wood, so that a striped and spotted effect is produced. As only completed articles can be fumed, the pieces constituting a set of furniture should be, if possible, made from a single tree and fumed simultaneously in one chamber, if they are to be alike in color. Spots are also produced by oil, glue, dirt and by careless handling of the articles before fuming, while after fuming the color, if not protected by varnish, is liable to be spotted and stained by water.

2. *Steaming.* Treatment with superheated steam has until recently been used only for the purpose of softening wood for bending, for example, in the manufacture of the well-known Thonet Vienna bent wood furniture, which is made chiefly of red beech. The coloring which is incidentally produced is uncertain and is therefore avoided as far as possible. Superheated steam, however, can be employed to produce a uniform brown color through the mass of the wood. The color is due to humin bodies resulting from partial decomposition of the lignin substances (sugar, gum, tannin, etc.). Superheated steam has recently been used in America for the purpose of drying timber, and a process of coloring might be advantageously combined with the drying process.

3. *Humin coloring of cut wood, by means of soil gases.* The principle of following nature as closely as possible is obeyed in a process, invented and patented by the writer, which is practically employed at an establishment near Dresden, with surprisingly good results. By this method, and by this alone, it is possible to produce in a comparatively short time the soft brownish gray color of age throughout the mass of large beams of every sort of wood, although not every wood is equally suited to the process. The most beautiful effect is produced with oak which, despite its closeness of texture, is colored throughout. Beech, alder and birch also give good results. Of resinous woods the larch and the American varieties, redwood, cypress, and pitch pine, give the best results, but even the European birch, pine and spruce quickly lose the raw color of freshly cut wood and develop the agreeable gray tones of age instead of the usually ugly yellow-gray color caused by light and air.

The new process differs essentially from the earlier tentative and disgusting methods of coloring wood by burying it in mud or animal excrement, and the result is also very different from the humin coloring of pieces of wood which have lain buried in swamps or moors for centuries. In the repulsive methods referred to, the effect is due to liquids, and is therefore more or less superficial. In the new process the coloring is effected by the natural gases of the soil, together with artificial gaseous additions. With a suitable composition of the soil, the unstable ingredients of the wood are decomposed and the stable parts are aged, ripened and softly tinted by the humin bodies. The change has nothing in common with ordinary decay, for it can be effected in a medium like coal ashes, which is entirely free from bacteria. The process may be briefly described as follows:

The wood, in the form of planks or beams, is laid horizontally on its edge in shallow pits, and covered with the prepared soil. The pits are about 20 inches deep and have a porous bottom. The soil should be neither a pure clay nor a pure sand, but a coarse-grained mixture containing a little humus. The size of the grain should range from one-eighth to one-fourth inch. Sifting is usually required to obtain this result. If no suitable natural soil is obtainable, moderately fine-grained coal ashes, which contain some unburned coal, instead of humus, may be employed. This material is continuously permeable for water and air and, when frequently sprinkled or exposed to rain, remains sufficiently moist, without long retaining liquid water. In the alternation of watering and drainage, air is copiously absorbed and a moist atmosphere is maintained in the soil. The oxidizing action of this moist air is greatly increased and modified by the addition of some substance which will evolve ammonia slowly and for a long time. After many experiments a perfectly clean mineral mixture was found to be a far more satisfactory source of ammonia than the foul messes formerly employed for this purpose.

The best result is obtained by adding lime and ammonia salts, or lime-nitrogen, to the soil in the proportion of one or two parts to a hundred. The chemicals are mixed with the soil by working with shovels on a board floor. In the mixing process the soil should be as dry as possible, in order to avoid rapid evolution and loss of ammonia. If ammonium sulphate is employed, the lime may be added in the form of ground limestone, which is cheaper and more satisfactory than either slaked or unslaked lime. The ammonium sulphate gradually dissolves in the moisture of the soil and reacts with the insoluble limestone, forming calcium sulphate and ammonium carbonate, which readily decomposes into ammonia and carbon dioxide. The gradual and long-continued formation of ammonium carbonate produces a much better effect than the direct addition of a large quantity of this salt, which is expensive and decomposes too rapidly, or than the rapid production of ammonia gas by the action of lime upon ammonia salts. The effect is especially good when care is taken to drain off all excess of water, to regulate the moisture and aeration of the soil and the slow and uniform production of ammonia, and to prevent the rapid escape of this gas from the pit. For this purpose the pit, filled with the prepared soil and boards, is covered with coarse sand or rags. Too little and too much moisture are equally injurious. Experience has shown that a large proportion of organic matter in the soil actually protects the boards from the coloring action of the ammonia and air, which in this case is exerted on the humus alone. Loose mineral soils containing a small proportion of humus or coal, on the contrary, allow the soil gases (air, water, vapor, ammonia, carbon dioxide and probably hydrogen dioxide) to produce the desired soft grayish-brown color of age in its full beauty. This result cannot be obtained by any other method.—Zeitschrift für angewandte Chemie.

BAGASSE AS A PAPER-MAKING MATERIAL.

IN an article published in the Tropical Agriculturist, W. Raitt points out that papers may be divided into three classes: the finest writing papers, made almost exclusively of rags, fine and medium writings and printings, and coarse unbleached papers, wrapping, etc. The raw material of the second of these groups is mainly wood, and this group represents 75 per cent of the whole of the paper consumed, or about six million tons yearly. It is only in class 2 that any serious shortage of raw material is threatened: the materials for class 3 are cheap and abundant. Sugar cane bagasse contains about 50 per cent of available cellulose, and a yield of 45 per cent of air-dried unbleached pulp might be expected on an industrial scale, but it cannot be regarded as a good material for the manufacture of papers of group 2. In most plants, the period of development at which the fibers are in their best condition is that which immediately precedes the maturing of the fruits or seeds. The sugar cane, being harvested for its juice, has not reached this stage of full development, and the fibers are irregular. While the fibers near the surface of the stem are long and strong, those in the interior are short and weak. The chemical treatment of the bagasse must then either be sufficiently severe to isolate and purify the outer fibers, in which case the interior fibers are largely destroyed, or else it must be modified to conserve the latter, in which case the strong outer fibers are not properly isolated. In the first case, the pulp is difficult to bleach on account of the decomposition products of the weaker fibers, and in the second case on account of the incrusting matters left in the stronger fibers. The author pronounces in favor of the milder type of chemical treatment, which, while eliminating bagasse from the possible substitutes for wood pulp in fine European papers, gives it an advantage for coarser papers for local consumption. The author estimates the value of bagasse as a raw material for papermaking at the sugar factory as 40 shillings per ton, while its value as a fuel is only about 7 shillings 6 pence per ton.

STUDENTS AND LUMBERJACKS.

THAT they may get experience at first hand in their study of forestry, forty students of the Biltmore (N. C.) School of Forestry and four members of the faculty are in camp near the Cummer-Diggins lumber camp.

The class is made up of young men from all parts of the United States and one Japanese. October 1st the class will go to Germany to study for six months in the Black Forest. Here the class will study forestry, botany, woods lore and all branches of the lumber business from the cutting of the trees to the manufacture of the lumber into the finished product, the mills here furnishing a basis for some of the studying.

A large percentage of the students are from families who are engaged in the lumber business, the desire being thoroughly to acquaint the future heads of large enterprises with the business, from the ground up.

The class is living a real lumberjack life and eats in the same mess with a camp of 150 jacks. Their place of recitation is a rural schoolhouse in the near neighborhood. Prof. Schenk, head of the Biltmore school, was for fourteen years forester on George Vanderbilt's $100,000 estate, on which the school is still located.

Young men find the school such a desirable means of education that there is always a long waiting list, and some are now looking forward even to April 1st, 1912, when they may join. Seventeen of the present party commenced their work here this week with the class, as many having completed their course just previous to the class coming to this city.—Detroit Free Press.

Glace Paper.—Parchment cuttings, 4 parts; isinglass, 1 part; gum arabic, 1 part; boiled down in 240 parts of water to one-half and filtered through a close cloth. The fluid is separated into three parts, in which, in order, 39, 32 and 35 parts of the finest white lead are rubbed down. This is applied with a broad, flat brush to the paper, each coat is allowed to dry thoroughly, and the smooth finish is given by passing it between polished calender rolls. In place of the white lead, zinc-white is often used.

EXPERIMENTS IN ANIMAL PSYCHOLOGY.

SOME OLD MYTHS EXPLODED.

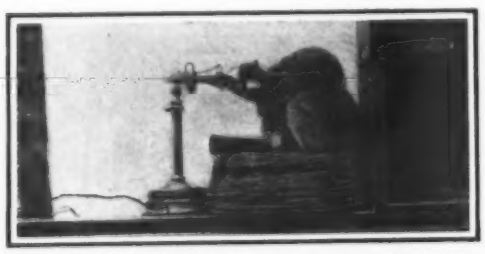
BY B. FORBIN.

HARVARD and Johns Hopkins organized a few years ago laboratories of experimental and comparative psychology, which have already enriched science. One of the questions attacked simultaneously by both laboratories is the following: "Is the education of animals accomplished by imitation, or is it entirely due to instinct?"

In this domain of animal psychology the most absurd fables are still repeated and accepted. The story of the artist who, to punish a monkey that had ruined his masterpiece, placed himself at the window, pretended to cut his throat, and on the next day had the pleasure of seeing his enemy commit suicide with a razor, is still to be found in certain textbooks. I do not know whether the enraged scorpion still continues to sting himself to death or not, but the newspapers last year printed, as an admirable example of conjugal fidelity, the story of a whale that deliberately stranded itself on the coast of Normandy after the death of its consort.

It is generally believed that the hunting and killing of mice is a natural and instinctive function of the cat. The incorrectness of this theory has been proved by the experiments of Dr. Berry of Harvard. The problem was to decide whether a young cat, seeing a mouse for the first time, would attack it instinctively, or would wait until it had been taught to do so. Three kittens, with their mother, were kept isolated from the external world from their birth until they were five months old and strong enough to kill the largest of mice. For the sake of clearness, we will designate the cat by the letter M and the kittens by X Y Z. When Z was placed in a cage with a large black mouse, it began to sniff the air and show symptoms of uneasiness. When the mouse moved, the kitten ran after it and struck it with its paw. A long game of hide-and-seek followed, during which the kitten did not once growl, or unsheath its claws. After the expiration of an hour the mouse was removed, and was found not to have received a scratch. The other two kittens behaved in the same manner. They played with the mouse, as all kittens play with any object which moves when touched, but did not endeavor to injure it. This initial experiment proved clearly that none of these three kittens exhibited any instinctive tendency to pursue, kill, and eat mice.

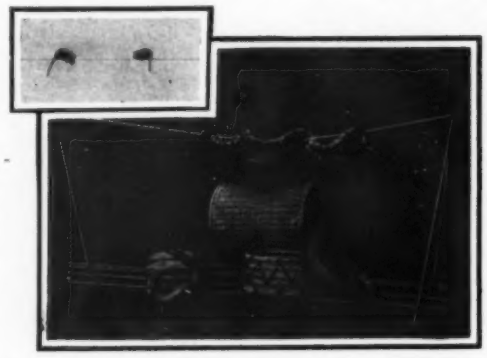
Six weeks later the experiment was repeated, each of the kittens being confined twenty minutes with the mouse. This time the kittens had fasted twenty-four hours. They were more lively than before and struck the mice more vigorously with their paws, but the mice still escaped without a scratch. An experiment was then made to ascertain how easily and rapidly the kittens could learn from their mother to perform a series of acts which instinct had not taught them. After the kitten X had played ten minutes with the mouse, the mother was placed in the cage with it. The cat instantly killed and devoured the mouse under the attentive eyes of her offspring. She was then removed



A MONKEY TAUGHT BY A DOG TO USE A TELEPHONE.

and a new mouse was introduced. Unmindful of the maternal lesson, X began to play with the mouse as usual. After a few minutes, the kitten Z was placed in the cage, and both kittens continued to play with the mouse. When one of the kittens held the mouse between its paws, it growled if the other threatened to deprive it of its prey. Z was then removed and replaced by the cat, which promptly killed the mouse. This time she allowed the kitten X to take the dead mouse in its mouth, but the kitten did not begin to eat the mouse until the mother had laid its flesh bare, after which it devoured the mouse greedily. These experiments prove that these three kittens, even when seven months old, did not possess an instinct impelling them to attack and devour mice, but that they learned to do so from their mother by imitation. Dr. Berry is careful not to make any hasty generalization, and he admits that facts in contradiction to the above experiment may be observed by others. The stories told by many travelers confirm the results of these laboratory experiments. For example, it is the habit of the lioness to bring small live animals to her den, apparently for the purpose of teaching her cubs to kill and eat them.

The following is a second interesting series of experiments performed with the same kittens. Six pieces of meat were placed in a milk bottle on a bed of paper which raised them to the desired height. The



A SNAKE LEARNING TO WALK A WIRE BY IMITATING MICE.

mother cat succeeded in extracting the meat with her paw, after four minutes' trial. The kitten Y attained equal success in ten minutes, but Z failed lamentably after twenty minutes' endeavor. With its muzzle buried in the neck of the bottle, Z tried to reach the meat by scratching the exterior of the bottle with its claws, or sought to insert its head and both forepaws together into the bottle. X adopted the same tactics, but varied them in a comical manner by dancing around the bottle with its forepaws inserted in the neck.

The third kitten Z subsequently solved the problem in an efficient manner, but X remained completely puzzled. On the fifth day, after X had struggled bravely with the bottle during forty minutes, Y was placed in the cage also. X followed attentively the maneuvers by which Y quickly extracted the six pieces of meat. Left alone with the bottle, which had been reprovisioned, X recommenced its former tactics, but soon, as if understanding that these were useless, it adopted the method, which it had seen employed by Z, of inserting one paw into the bottle, and in less than two minutes extracted the six pieces of meat. After this X performed the task as skillfully as the other kittens.

The above are two simple types of a long series of experiments, in some of which special boxes and cages, which the animal had to open in order to obtain food, were employed, and which tend to prove that animals acquire their education by a combination of unconscious or instinctive imitation and voluntary imitation.

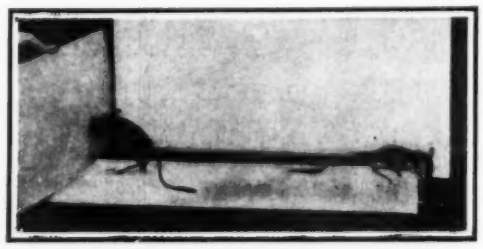
We will now describe briefly some far more complicated experiments performed in the same laboratory by M. E. Haggerty with animals celebrated for their imitative faculties and general intelligence; namely, monkeys of the species *Cebus lunatus*. The monkeys were placed in a cage 6½ feet high, 4 feet long, and 3 feet wide, closed on two sides by boards and on the other two by bars. The solid roof of the cage was pierced near one of the barred sides by a trap door 4 inches square, which opened inward and was fastened with a bolt. Another opening in the roof, near the opposite wall of the cage, admitted a sort of chimney, which projected 2 feet below the roof. In this chimney hung a cord which when pulled would slide back the bolt of the trap door. The top of the chimney was covered to prevent the entrance of light, and the lower end of the cord was 4 inches higher than the bottom of the chimney, and consequently could not be seen from the interior of the cage. Nuts and fruit were placed on the trap door. In order to obtain the food, it was necessary for the monkey to climb half way up the bars of the cage, leap to the chimney, and, clinging with three paws to its lower part, to insert the fourth paw into its lower opening, seize and pull the cord connected with the bolt of the trap door, and finally to descend to the floor of the cage to pick up the fallen food. It will be admitted that this was asking the poor creature to work very hard for a few nuts.

Now let us see how this complicated test was met by the two monkeys Jack and Jill in the course of a daily series of half-hour lessons. Jack, placed alone in the cage for the first time, soon sprang upon the chimney, but paid no attention to its mouth. On the following day, he bounded across the cage so violently that the trap opened. After he had eaten the fallen nuts, Jack climbed up the bars of the cage and, holding on with his feet, he grasped the open trap door with his hands and put his head through the opening. It seemed as if he had discovered the source of the food by association of ideas and was in a fair way to solve the problem. Thereafter he made rapid progress. After springing repeatedly from the bars to the chimney, he seemed to conceive the idea of hanging by his tail and hind feet and inserting his head and arms into the mouth of the chimney. As soon as he had done so and had perceived the cord, he gave a vigorous pull. The trap opened, and Jack hastened to devour the fallen food. Although he appeared to have already found the solution, he then sprang about the cage and leaped upon the chimney twenty times in as many minutes without paying any attention to its open mouth. He was shut up in the cage for half an hour on three consecutive days without attaining any result. Finally, two weeks after the commencement of his education, he definitely mastered the problem, and operated the machinery ten times in twenty-seven minutes.

Jill did not display equal aptitude. Placed fasting in the cage, she sought carefully for food and climbed up the bars, but without paying any attention to the chimney. She behaved in the same manner for eleven successive days, searching every corner of the cage and every crack of the floor and growling angrily, but without once springing to the chimney, although she often nearly touched it in her wild leaps. It was evident that she would never solve the problem without assistance, and it was decided to see what effect Jack's example would have upon her.

The two monkeys were placed together in the cage. Jack operated the machinery with remarkable dexterity seven times in ten minutes. Jill had followed two of the operations attentively, and four others to some extent. Jack was then removed and Jill left alone for half an hour. After leaping about the cage as usual, she stood on her hind feet under the chimney, as if trying to find out what it contained, then she climbed up the bars, as if for the purpose of leaping to the chimney, but did not do so. The example of her companion had produced no effect.

Jack was again placed in the cage with her, and Jill eagerly took her share of the food, which Jack obtained by working the trap. But when Jill was left alone again, she showed herself as stupid as before. These experiments were repeated during the sixteen following days, and Jack operated the machinery 153 times in Jill's presence without producing any result. The utmost that Jill did was to climb up the bars and advance her head and arms toward the chimney. The idea never entered her brain that she had only to make a leap and pull the cord in order to bring to her feet a banquet of nuts and bananas. In the face of these



TEACHING GERBOAS TO DANCE.

results, what becomes of the tradition that monkeys are the most imitative animals in the world?

The above are only a few of the numerous interesting observations made in the American laboratories, which are now experimenting with animals less intelligent than cats or monkeys, in order to ascertain whether one animal will imitate an animal of a different species. For example, if a snake sees a mouse walk on a stretched wire, is the small reptilian brain capable of grasping the idea that it is possible to travel along this oscillating path in search of food? After seeing and hearing a dog bark before a telephone and receive a piece of meat as a reward, will a lemur perform the same act for a banana, or by a similar process can a gerboa be taught to dance?—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from La Nature.

A POSSIBLE EXTENSION OF THE PERIODIC LAW.

A CONSIDERATION OF THE LOTHAR MEYER CURVE FOR 1909.

BY O. IVAN LEE.

IN a footnote in his "Principles of Chemistry,"* D. Mendeléeff under the methods with which he was then acquainted of expressing the periodic relations of the elements, summarizes:

"By a curve drawn through points obtained in the following manner: The elements are arranged along the horizontal axis as abcissae at distances from zero proportional to their atomic weights, while the values for all the elements of some specific property—for example, the specific volumes or the melting points, are expressed by the ordinates. This method, although graphic, has the theoretical disadvantage that it does not in any way indicate the existence of a limited and definite number of elements in each period. There is nothing, for instance, in this method of expressing the law of periodicity, to show that between magnesium and aluminium there can be no other element with an atomic weight of, say, 25, atomic volume 13, and in general having properties intermediate between those of these two elements. The actual periodic law does not correspond with a continuous change of properties, with a continuous variation of atomic weight—in a word, it does not express an uninterrupted function—and as the law is purely chemical, starting from the conception of atoms and molecules which combine in multiple proportions, with intervals (not continuously) it *above all* depends on there being but few types of compounds, which are arithmetically simple, *repeat themselves*, and offer no uninterrupted transitions, so that each period can only contain a definite number of members."

If the atomic volumes of the elements are thus plotted against their atomic weights, and a line drawn connecting the points so obtained, the curve results, that was first constructed by Lothar Meyer and known by his name. In chemical text books, attention is directed to the periodic character of the curve and its relation to the periodic table, the loops corresponding to the short and the long periods; the transitional elements of periods III, IV, and VI being found at the minima of the large hollows; separating the even series (situated on the descending portion of the curve) from the odd series which lie on the ascending slope; elements of the different groups occupying the same relative positions upon the different portions of the curve; and the five alkali metals, Li, Na, K, Rb and Cs, being found upon the maxima of the curve, the heavier electro-positive elements (such as Cu, Ag and Au) reappearing at the minima. Relations between a number of other physical properties and atomic volumes have been pointed out. These include refraction of light, specific heat, power to conduct heat and electricity, magnetic properties and fusibility, the last being the most interesting and the most closely allied.

In the curve shown here, where several allotropic modifications of an element are known to exist, the atomic volume has been taken of that form which is the most stable and the most characteristic, and crystalline rather than amorphous. In the case of carbon, for instance, graphite (at. vol. 5) has been chosen in preference to diamond (at. vol. 3.4); and also in order that this element should lie in the same relative position on the curve as Ge, Sn and Pb. The density taken for gaseous elements refers to the liquid state, data regarding the solid being unfortunately meager.

Leaving out of consideration, for the present, the first two (typical) elements of the groups, it will be noticed that a straight line can be drawn which will pass very nearly through the points K, Rb and Cs. The same holds true for Ca, Sr and Ba. Taking Group O, a line can be drawn which will pass exactly through A, Kr and Xe, and another also through Cl, Br, and I.† Continuing, lines can be similarly ruled through Yt, La; As, Sb, Bi; Ti, Zr, Ce, Th; Ge, Sn, Pb; Ga, In, (Er), Tl; Zn, Cd, Hg; V, Nb, (Pr), Ta; Cr, Mo, (Nd), W, U; Cu, Ag, Au; Ni, Pd, Pt; Co, Rh, (Gd), Ir; and Fe, Ru, Os, in the order given, the variation from the mean becoming less as the more electro-positive elements are reapproached. Those elements in parenthesis, however, exhibit a marked variation, to which reference will be made later.

The mean line for Se and Te is the mean also for O and S, thus apparently including the typical elements in one instance. It will be observed, too, that the line through Mn and Sm runs diagonally across the lower lines which may be designated for convenience as the metallic majority.

Returning, now, to the typical elements, the line through Li and Na intersects the K Rb Cs line a little more than half way between K and Rb. The Be Mg line meets the Ca Sr Ba line proportionately nearer Ca; and the line of B and Al crosses the Yt La line *just behind the intersection of the latter with the curve at a point whose ordinate is* 44.5. *The atomic weight of Scandium, the element preceding Yt, is* 44.1. Also, the C Si line intersects the Ti Zr Ce Th line *in front* of Ti. Selecting the limiting atomic volumes of C and Na, possible densities of solid N, O and F can be calculated from the assumption that the atomic volume of each of these elementary gases is roughly proportional to its atomic weight, the respective specific gravities resulting being 1.44, 1.38, and 1.15. By the employment of a similar method, the atomic volumes of liquid He and Ne are found to be about 5.1 and 17.2, respectively. Type line He Ne can now be drawn, the negative slope of N P corrected, line H F fixed with greater accuracy, and the true slant of O S determined.

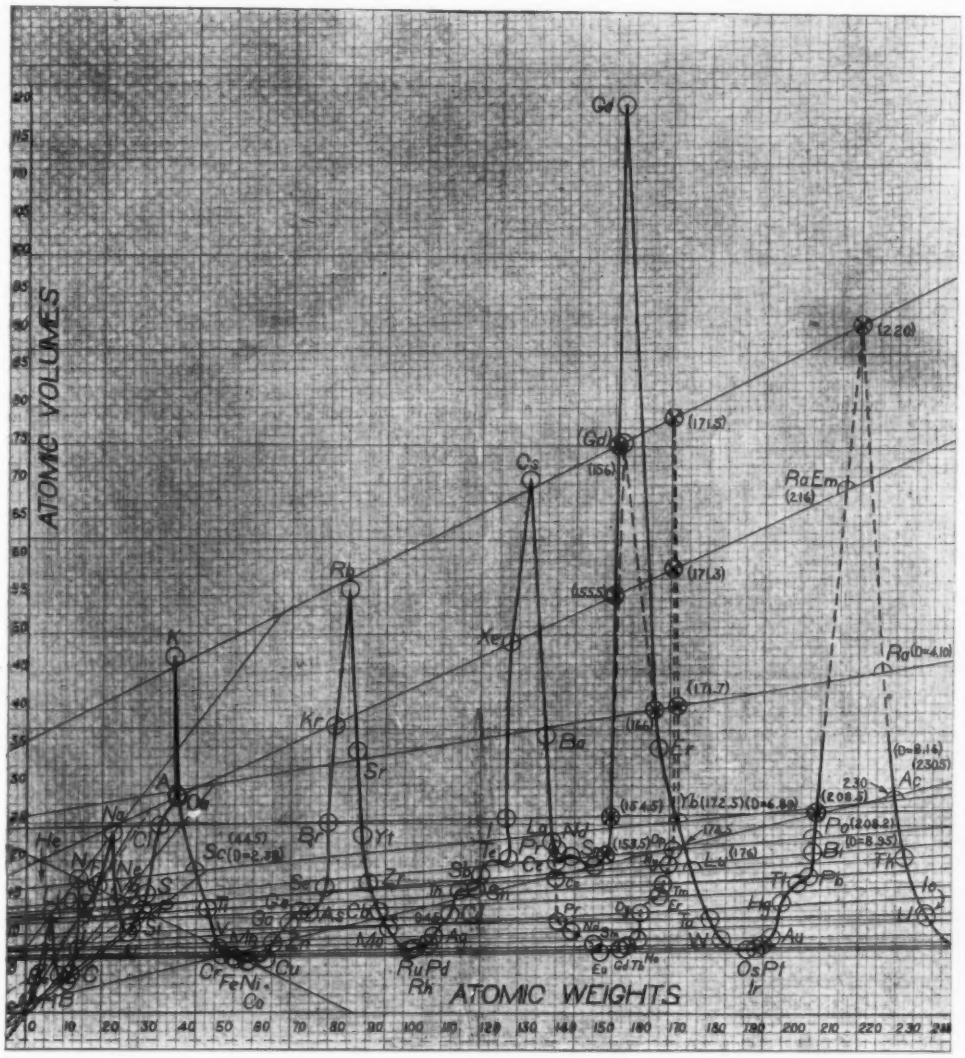


DIAGRAM SHOWING THE CURVE OF ATOMIC VOLUMES AND ATOMIC WEIGHTS OF THE ELEMENTS.

The precession of the type lines along coresponding group lines can be traced completely; and it will be found that *the lines of the typical elements show a tendency to revolve clockwise in the order of their groups*, from an angle of about 60 for the H F line to about 30 for that of Os S.

The slope of the Argon group would doubtless not be so steep if the density of the solid gases were determined. Likewise the densities of solid chlorine and and bromine should determine a more consistent slant than their line has at present. The fact that I, a solid, is exactly on the line of Cl and Br, liquids, can be accounted for by a slight difference in the density of solid and liquid I.

The relation implied by the foregoing observations may be stated as follows:

Omitting the typical members, the atomic volumes of elements of the same chemical family constitute a rectilinear function of their respective atomic weights, the location of each element being determined by the periodic intersection of its series line with the Lothar Meyer curve, Group VIII being read vertically.

That is, given the true atomic weight of an element, its approximate specific gravity can be established, and also the position of the element in the periodic table.

In the diagram, elements of doubtful position or of unknown atomic volumes, are designated by semicircles, and undiscovered elements by crossed circles. A parenthetical number refers to the graphical value of an atomic weight, or to a density calculated from the graphical value of an atomic volume.

A glance at the curve will show that the loop to the right of Cs is not as deep as might be expected, and that many of the lines never meet this portion of the curve. Again, the elements here belong to the rare earth class and are exceedingly difficult to isolate, both as salts and as elements, the latter being more often described as semi-coherent powders than as true metals. "Elements" of this kind have several times proved mixtures of similar properties and atomic weights. Bearing in mind these facts, it is not strange that this loop should be so irregular and at variance with the others. Granting the definite relation between atomic weights and atomic volumes above given, it is plain that unless the densities of Sm, Pr, Nd and Ce are redetermined and values found which will admit of their atomic volumes being lowered, the elements now tabulated as missing under Ru, Rh, Pd, Ag, Cd, Sn and Sb, will never be discovered for the reason that they can not exist, no intersection of this part of the curve being possible with the aforementioned series lines. There is good reason to believe, though, that these missing elements do exist; and further, it can be independently substantiated that the density of Sm is too low.

Three members of the Mn series are at present unknown, of atomic weights as indicated by the periodic classification, arithmetically approximate to 98 (Ram-

* Science, vol. ii., part 3, p. 19, note 10.

†The remarkable equality of the atomic volumes of the halogens (F excepted) is mentioned by Mendeléeff.

say, Mo + 2), 185 (W + 1) and 240 (U + 1.5). *The Mn Sm line, as it stands, crosses the curve at points whose ordinates are* 94.5, 174.5 *and* 230. If it harmonized with the metallic majority, these values would be rectified, and the discovery made possible of an element with a higher atomic weight than uranium.

An adjustment of the atomic volume of an element *downward* can be much easier accommodated than a change of atomic weight in either direction, which would usually warp the curve; and it is noteworthy that a corresponding *increase* in density can be most easily tolerated by the elements whose atomic volumes are most in need of revision and whose metallic characteristics are not well defined; viz., Yt, Pr, Nd, Sm, Er and Gd. A consideration of the change in atomic volume necessitated by the latter is particularly interesting with regard to what has been said of samarium.

Because of its trivalence and other chemical properties, Gd can not be placed on the line of K, Rb, and Cs as indicated; neither is it conceivable to class it with the Cl, A or Ca group. Eu (152) seems logically placed after Sm (150.4) under Ru, and as Gd has the next highest atomic weight (157.3), it falls under Co and Rh. Putting the remaining rare elements in the order of their atomic weights, Tb (159.2), Ho (162), Dy (162.5), Er (167.4), Tm (168.5), Ny (170±) and Dp (171) fall respectively under Pd, Ag, Cd, In, Sn, Sb and Te. Dropping Pr, Ce, Nd and Sm and displacing the curve (dotted) through these elements as well (all shown by circles for clearness), give a loop which appears much more symmetrical than the original one drawn in a full line. The atomic weight, 171, of Dp, fits into the periodic table much better, also, than the present graphical value of 153.5. Since the four elements under I, Xe, Cs and Ba must have atomic weights ranging from 171 to 172 (Yb), they will probably be found difficult to separate from one another, as is noticeable to a less degree in known elements having nearly the same atomic weight; viz., Co and Ni, Sn and Sb, and Os, Ir and Pt.

It is difficult to conceive the significance, if there is any, of the convergence of the lines unless a literal interpretation is put upon it as pointing to the ghost of a Prout's hypothesis; but, if so, implying a condensation from something far more subtle than hydrogen. The curve itself is suggestive of an oscillation whose origin might not unreasonably be identical with that of the group lines, and although the type lines are perverse, they *tend* to point in this direction. Measurements which have been made, locate the origin at + 6, — 237.5.

There is undoubtedly a close connection between other properties of the elements and their atomic weights; but except for the melting point, data are incomplete and subject to modifying physical conditions. The relation herein set forth, if true, seems capable of supplementing the usefulness of the periodic law, and of serving to supply desirable quantitative information of the atomic volumes of the elements, both known and undiscovered.

THE ISOLATION OF AN ION.—II.*

A PRECISION MEASUREMENT OF ITS CHARGE AND THE CORRECTION OF STOKES'S LAW.

BY PROF. R. A. MILLIKAN, UNIVERSITY OF CHICAGO.

Continued from Supplement No. 1814, Page 240.

5. DISCUSSION OF TABLE NO. I.

SINCE the original drop was in this case negative, it is evident that a sudden increase in the speed due to the field, that is, a decrease in the time given in column *F*, means that the drop has caught a negative ion from the air, while a decrease in the speed means that it has caught a positive ion. If attention be directed, first, to the latter part of the table, where the observations are most accurate, it will be seen that beginning with the group for which *G*=23.43, the time of the drop in the field changed suddenly from 71 sec. to 380 sec., then back to 71, then down to 39, then up again to 71, and then up again to 380. These numbers show conclusively that the positive ion caught in the first change, i. e., from 71 to 380, carried exactly the same charge as the negative ion caught in the change from 380 to 71. Or again, that the negative ion caught in the change from 71 to 39, had exactly the same charge as the positive ion caught in the change from 39 to 71.

Furthermore, the exact value of the charge caught in each of the above cases is obtained in terms of *mg* from the differences in the values of c_n given by equation (1), and if it be assumed that the value of *m* is approximately known through Stokes's law, then the approximately correct value of the charge on the captured ion is given by the difference between the values of c_n obtained through equation (4). The mean value of this difference obtained from all the changes in the latter half of Table I. (see differences) is 4.93×10^{-10}.

Now it will be seen from the first observation given in the table that the charge which was originally upon this drop and which was obtained not from the ions in the air, but from the frictional process involved in blowing the spray, was 34.47×10^{-10}. This number comes within one-seventh of one per cent of being exactly seven times the charge on the positive or on the negative ion caught in the observations under consideration. Mr. Harvey Fletcher and myself, who have worked together on these experiments since December, 1909, studied in this way between December and May from one to two hundred drops, which had initial charges varying between the limits 1 and 150, and which were upon as diverse substances as oil, mercury and glycerine, and found in every case *the original charge on the drop an exact multiple of the smallest charge which we found that the drop caught in the air.* The total number of changes which we have observed would be between one and two thousand, and *in not one single instance has there been any change which did not represent the advent upon the drop of one definite invariable quantity of electricity, or a very small exact multiple of that quantity.* These observations are the justification for assertions 1 and 2 of the introduction.

Before discussing assertion 4 it is desirable to direct attention to three additional conclusions which can be drawn from table I:

First, since the time of the drop in the field varied in these observations from 380 seconds to 6.7 seconds, it will be seen that the resultant moving force acting upon the drop was varied in the ratio 1 to 55, without bringing to light the slightest indication of a dependence of e_n upon the velocity. Independently of theory, therefore, we can assert that the velocity of this drop was strictly proportional to the moving force. The certainty with which this conclusion can be drawn may be seen from a consideration of the following numerical data. Although we had upon our drop all possible multiples of the unit 4.917×10^{-10} between 4 and 17, save only 15, there is not a single value of c_1 given in the table which differs by as much as 0.5 per cent from the final mean e_1. It is true that the observational error in a few of the smaller times is as much as 1 or 2 per cent, but the observational error in the last half of the table should nowhere exceed 5 per cent. In no case is there here found a divergence from the final value of e_1 of more than 0.4 per cent.

Second, since the charge on the drop was multiplied more than four times without changing at all the value of *G*, or the value of e_1, the observations prove conclusively that in the case of drops like this, the drag which the air exerts upon the drop is completely independent of whether the drop is charged or uncharged. In other words, the apparent viscosity of the air is not affected by the charge in the case of drops of the sort used in these experiments.

Third, it will be seen from the table that in general a drop catches an ion only when the field is off. Were this not the case there would be many erratic readings in the column under *F*, while in all of the four and one-half hours during which these experiments lasted, there is but one such. A moment's consideration will show why this is. When the field is on, the ions are driven with enormous speed to the plates as soon as they are formed, their velocities in the fields here used being not less than 10,000 centimeters per second. Hence an ion can not be caught when the field is on unless the molecule which is broken up into ions happens to be on the line of force running from the plates through the drop. With minute drops and relatively small ionization this condition is very unlikely to occur. When the field is off, however, the ions are retained in the space between the plates and sooner or later, one or more of them, by virtue of its energy of agitation, makes impact upon the drop and sticks to it.

These considerations lead up to assertion 4 in the introduction. It will be seen from the readings in the first half of the table that even when the drop had a negative charge of from 12 to 17 units it was not only able to catch more negative ions, but it apparently had an even larger tendency to catch the negatives than the positives. Whence then does a negative ion obtain an amount of energy which enables it to push itself up against the existing electrostatic repulsion and to attach itself to a drop already strongly negatively charged? It can not obtain it from the field, since the phenomenon occurs when the field is not on. It can not obtain it from any explosive process which frees the ion from the molecule at the instant of ionization, since again in this case, too, ions would be caught as well, or nearly as well when the field is on as when it is off. *Here then is an absolutely direct proof that the ion must be endowed with a kinetic energy of agitation, which is sufficient to push it up to the surface of the drop against the electrostatic repulsion of the charge already on the drop.*

This energy may easily be computed as follows: As will appear later the radius of the drop was in this case 0.000197 centimeter; furthermore, the value of the elementary electrical charge obtained as a mean of all of our observations, is 4.901×10^{-10}. Hence, the energy required to drive an ion carrying a unit charge up to the surface of a charged sphere of radius *r*, carrying sixteen elementary charges, is

$$\frac{16\,e^2}{r} = \frac{16 \times (4.901 \times 10^{-10})^2}{0.000197} = 1.95 \times 10^{-14} \text{ ergs.}$$

Now the kinetic energy of agitation of a molecule as deduced from the value of *e* herewith obtained, and the kinetic theory equation,

$$p = \tfrac{1}{3}\, nmu^2 \text{ is } 5.756 \times 10^{-14} \text{ ergs.}$$

According to the Maxwell-Boltzmann law, which doubtless holds in gases, this should also be the kinetic energy of agitation of an ion. It will be seen that the value of this energy is approximately three times that required to push a single ion up to the surface of the drop in question. If, then, it were possible to load up a drop with negative electricity until the potential energy of its charge were about three times as great as that computed above for this drop, then the phenomenon here observed, of the catching of new negative ions by such a negatively charged drop, should not take place, save in the exceptional case in which an ion might acquire an energy of agitation considerably larger than the mean value. Now, as a matter of fact, it was regularly observed that the heavily charged drops had a very much smaller tendency to pick up new negative ions than the more lightly charged drops. And in one instance Mr. Fletcher and myself watched for four hours a negatively charged drop of radius .000658 centimeter, which carried charges varying from 126 to 150 elementary units, and which therefore had a potential energy of charge (computed as above on the assumption of uniform distribution) varying from 4.6×10^{-14} to 5.47×10^{-14}, ergs, and *in all that time this drop picked up but one single negative ion, and that despite the fact that the ionization was several times more intense than in the case of the drop in Table* I. This is direct proof independent of all theory that the order of magnitude of the kinetic energy of agitation of a molecule is approximately 5×10^{-14}, as the kinetic theory demands.

The first portion of assertion 5 is directly proven by the readings contained in the table, since the great majority of the changes recorded in column 4 correspond to the addition, or subtraction of one single elementary charge. The second portion of the assertion seems at first sight to be proven by the remaining changes which correspond to the addition or subtraction of two or three times this amount. The conclusion, however, that valency is exhibited in gaseous ionization is not to be so easily drawn. The arguments for it which are furnished by our experiments will be presented fully elsewhere. Space here only permits the statement that the only strong argument furnished by Table I. is found near the end of the table where, *when the field was on, the drop caught a double negative ion while I was looking at it.*

Some idea of the intensity of ionization used in these experiments may be gained from the statement that during the observations recorded in the first half of the table, a closed tube of radium, containing 500 milligrams of radium bromide of activity 3,000 stood about five feet away from the testing chamber, so that

* Paper read before the American Physical Society.

lis γ rays could enter this chamber. At the end of the observations in the group in which G=23.14, this radium was brought up to within a few inches of the testing chamber, and six elementary charges were forced upon the drop in a manner which will be presently explained. The radium was then taken entirely out of the room, so that the changes recorded in the last half of the table are entirely due to such ionization as exists in air under normal atmospheric conditions.

There is but one more comment to be made upon Table I. At a point indicated in the table by the remark "change forced with radium," it will be noticed that the charge was suddenly changed from eleven negative units to five negative units, i. e., that six positive units were forced upon the drop. This sort of a change was one which, after the phenomenon had once been got under control, we could make at will in either direction; i. e., we could force charges of either sign or in any desired number, within limits, upon a given drop. We did this as follows: when it was desired to load the drop up negatively, for example, we held it with the aid of the field fairly close to the positive plate, and placed the radium so that it would produce uniform ionization throughout the chamber. Under these conditions, if the positive and negative ions were alike in number and mobility, the chance that the drop would catch a negative ion would be as many times its chance of catching a positive ion as the distance from the drop to the negative plate was times the distance of the drop to the positive plate. Similarly, if we wished to load the drop positively it was held by the field close to the negative plate. On account of the slightly greater mobility of the negative ions and also on account of the somewhat greater numbers in which they occur, we found, in general, a slightly greater tendency of the drops to take up negative than positive charges. In view therefore of the greater ease with which negative drops could be held for long intervals without being lost to the plates, most of the drops studied have been of negative sign.

(To be continued.)

ASTRONOMICAL RESEARCH.*

ITS AIMS AND METHODS.

BY S. S. HOUGH.

THE universe of so-called "fixed stars" is not invariable in aspect, though its changes for the most part are of so minute a character that they can only be surely detected either by the most delicate measurements or by their cumulative effect over long intervals of time. Among changes which lend themselves to observation we may enumerate (1) changes of the intensity of the light of the stars. The origin of these changes, except in a few instances, remains obscure. In certain cases, however, notably in the case of variable stars of the Algol type, a satisfactory explanation of the observed phenomena has been found in the motions of a system governed by laws similar to those operating in our solar system of which the visible star forms a constituent member; (2) changes of position due to orbital motion in binary or multiple stars. Where both components of a binary star are visible, these changes readily admit of direct measurement. In other cases, the existence of a companion is inferred to account for regular periodic changes of position of the visible component, though this companion cannot be seen either on account of intrinsic want of light or on account of its close proximity to the primary, and the consequent incapacity of our telescope to render the two visually distinct. These changes are of interest as affording evidence of the validity of the Newtonian laws in systems other than the Solar System. The changes to which I have so far referred are changes which affect isolated stars or groups of stars, but which do not occur, at least to a sensible extent, in the generality of stars. I come now to the changes of position due to the earth's orbital motion, which, on the other hand, may be expected to influence all stars in common. Even where, as in the cases I have already spoken of, their influence is obscured by orbital motion within the system, when once this orbital motion has been thoroughly examined, its laws deduced, and due allowance made for it by computation, we might expect to find the effects of the earth's motion still apparent. The earth in its orbit round the sun approximately describes a circle of 186,000,000 miles in diameter, and its successive positions in space at intervals of six months are separated from one another by this extent. But experience has shown that recurring changes in the relative positions of the stars, as viewed at intervals of six months—that is to say, from two different points of the universe separated by this vast distance—can only be detected in the case of a limited number of stars, and then only by the application of the most delicate methods of measurement specially designed to bring these changes to light. To the Cape Observatory and its former director, Henderson (1832-4), belongs the credit of first producing reliable evidence of any fixed star, for which these changes could be unmistakably detected, and which, therefore, was not too remote from the Solar system to permit of its distance being at least roughly determined in comparison with the diameter of the earth's orbit. Henderson's discovery has since been fully confirmed by later observers, and other stars likely to yield tangible results have now been examined. As illustrative, however, of the evasiveness of the quantities sought, and the excessive labor by which only they can be derived, though the problem of stellar distance has always been in the forefront of astronomical interest, and has attracted the attention of several able observers, the number of stars for which well-determined parallaxes have been published up to the present day does not exceed some 400. This number is quite insignificant in comparison even with the number of stars visible to the naked eye without telescopic aid. Moreover, the stars investigated have been in general selected on the grounds of some *a priori* probability of their possessing a measurable parallax, either on account of apparent brightness, or on account of their large apparent motion, and for this reason they can scarcely be regarded as typical of the generality of stars. In order, then, to gage the depths of the visible universe, it would appear imperative that our base-line must in some manner be extended. The distance of 186 million miles, through which we are carried in the course of a single half-year by the orbital motion of our planet round the sun, is so small in comparison with interstellar distances as to give rise to changes in the apparent relative positions of stars which, except in the most pronounced instances, are so insignificant in amount as to defy detection even by the most refined processes of measurement we possess.

MOTION OF THE SOLAR SYSTEM.

How, then, can such an extension of our base-line be attained? I have already pointed out that the so-called "fixed stars" are not truly "fixed," but that on close observation it is found that each star has an apparent motion either peculiar to itself or shared by other neighboring stars which, with it, constitute an independent system. I refer primarily to the visible motion transverse to the line of sight. If, then, our sun, as we may reasonably suppose, is itself a member of the stellar universe, it may be anticipated that it too will not be at rest, but will be moving forward in space, and the visible motions will be those due to the combined effects of the motion of the sun and stars. That the apparent motions of the stars were not entirely fortuitous, but that they could at least partially be co-ordinated throughout the sky as the visible manifestation of a single phenomenon, viz., a translatory motion of the sun with its system of planets through interstellar space was first pointed out by Sir Wm. Herschel, who further indicated that the point of space to which this motion was directed was situated in the constellation "Hercules." Before proceeding to the further consideration of this solar motion, I wish first to point out to you how its existence at once suggests a means of "extending our base-line" for the purpose of gaging these interstellar depths. I have refrained from any numerical estimates of the amount of this motion, as this involves philosophical questions into which I do not desire to enter to-night. But in order to fix our ideas, it is necessary for me to give you some notion at least of the order of magnitude. It is now possible to state with some certainty that the speed of the sun's motion relatively to the stars as a whole amounts to about 20 kilometers per second, and that the space traversed in a single day therefore amounts to rather over a million miles, that in a year to about 400,000,000 miles. Thus the stars, as seen on two occasions a year apart, may be considered as viewed from two points in space separated by this length, and it only requires lapse of time in order to increase the length to an almost indefinite extent.

MAPPING THE HEAVENS.

The great scheme for the photographic mapping of the heavens at present being carried out on an extensive scale by means of the co-operative efforts of the leading observatories of the world, will shortly furnish a highly accurate delineation of the skies as seen at the commencement of the twentieth century. This alone has called for concentrated effort extending over some 12 years at least, while it would even now scarcely be safe to say that another ten years will see its completion. An immediate repetition is scarcely to be contemplated, though a subsequent repetition at some future epoch, which may be agreed on by astronomers, forms an essential part of the programme as originally introduced. When this scheme is completed in its entirety, very ample data will be available for the discussion of stellar distribution by the methods I have suggested to you. In the meantime, however, in such tentative attempts as have been made to fathom the secrets of the universe by means of the study of stellar proper motion, it has been necessary to rely on early recorded exact observations. It will be clear, from what I have already explained to you, that it is the earliest reliable records in comparison with the most up-to-date available which will yield the greatest length of base-line, and consequently the most trustworthy results. For this reason, the majority of the discussions hitherto attempted have been based on the catalogue of Bradley, dependent on observations made by him at Greenwich between the years 1750-1762. This catalogue contains the places of some 3,000 stars observed with a precision far surpassing any similar previous observations and comparing favorably with the best modern catalogues. The stars selected by Bradley are fairly uniformly distributed over the portions of the sky accessible to him—viz., from the North Pole to 30 deg. south of the Equator. Unfortunately, no early catalogue of stars of even approximately similar precision exists for the remaining region of the sky between 30 deg. S. Decln. and the South Pole, and the absence of exact knowledge of these regions for the earlier epochs has always hampered these discussions. The discussions I refer to have generally had as their immediate objective (1) The determination of the precessional constant—i. e., the annual amount by which the earth's axis of rotation changes its position in space; and (2) the determination of the speed of the solar motion and the position of the solar apex—i. e., the point in the heavens toward which the sun's motion is directed.

KAPTEYN'S THEORY.

The discrepancies in these quantites found by different investigators either starting with different data, or utilizing different methods for the combination and discussion of the same material, had long been a puzzle to astronomers. The key to the situation was at length furnished by Prof. Kapteyn, of Groningen, who, in an epoch-making paper, read before the British Association in Capetown, first pointed out that the apparent motions of the stars indicated not merely the existence of a single solar apex, but that there were two separate regions of the sky toward which a preference was shown by the directions of motion of the Bradley stars. This was a phenomenon which could not be explained by a simple motion of translation of the sun, as evidently the sun's motion could not be directed to two different points simultaneously, and the only feasible explanation was that the stars consisted of two groups, and that the motion of the sun relatively to one of these groups differed from its motion relatively to the other; or that, though the stars appeared intermingled in space, they possessed an independent relative motion, which might be regarded as located in one group or in the other, but which was shared by all the stars peculiar to the group. The theory of the existence of two streams or drifts of stars thus put forth by Kapetyn has since received full confirmation by other investigators, notably by Eddington, who based his examination on the early observations of Groombridge, and by Dyson, who limited his discussion to a selected list of stars possessing considerable proper motions. Recent investigations at the Cape, to which I shall refer later, have led us to examine in somewhat more minute detail the proper motions of the Bradley stars, with the result that, though the phenomena first noticed by Kapetyn stand out as the most prominent feature,

* From an address delivered by the President of the Royal Society of South Africa.

certain subsidiary features of no less importance have been brought to light. It will be clear that, if we fix our attention on stars situated in the region of the sky immediately surrounding the solar apex, the transverse motion of the stars due to the sun's own motion must vanish. The same will be true for stars situated near the anti-apex, or region from which the sun is receding. The transverse motion will be greatest for stars on a zone situated halfway between these two points. In the case of a double drift, as suggested by Kapteyn, it is clear that the only detectable systematic motions in the neighborhood of the apex or anti-apex of the first drift will be those of stars belonging to the second drift, and vice-versa. In all cases the actual drift motions are obscured by the peculiar motions of individual stars, and this, in combination with the facts—that in certain regions of the sky the influence of one or other drift will predominate, in certain other regions the drifts will give rise to transverse motions in similar directions, while in yet other regions they will be directly opposed—renders the separation of the stars into their component drifts a question of very considerable delicacy. The difficulties in a large measure disappear if we confine our attention to regions of the sky directly opposite to one another. In such regions the effects of foreshortening due to the inclination of the line of vision to the direction of drift velocity will be exactly similar, and any want of symmetry between such regions must be attributed to other causes. These irregularities in distribution in the stars of the second drift, which seem to have no counterpart in those of the first, it should be borne in mind, are the outstanding features over and above the fortuitous elements which pertain to individual stars. Thus we arrive at the, at first sight, paradoxical conclusion that, while the first drift stars are distributed at random throughout the sky, the very irregularities pertaining to the second drift point to some kind of structural unity in this drift. Before attempting to explain this further, I wish to draw attention to an entirely different method of investigation by which the phenomena I have been discussing may be examined.

THE SPECTROSCOPE OF STAR MEASUREMENT.

I have concerned myself hitherto only with the visible motions of the stars transverse to the line of sight, as derived by the older methods of measurement. The introduction of the spectroscope into astronomical research has opened up vast new fields into which, so far as they relate to the chemical and physical constitution of the sun and stars, it is not my purpose to enter to-night. What I wish rather to emphasize is the value of this instrument as a supplement to the older methods in relation to the geometrical astronomy of position. In accordance with the principle laid down by Doppler, the wave-length of light received from a source which is either receding from or approaching a receiver, will appear to be modified by an amount dependent in a known manner on the velocity of approach or recession. If the receiver takes the form of a spectroscope which permits by any means, direct or indirect, of the measurement of the wave-lengths, and the normal wave-lengths of the lines under examination are independently determined by laboratory investigations, the difference between the observed and the normal wave-lengths will thus afford a means of measuring the velocity of approach or recession of the source of light. Of the precautions necessary to insure precision, it is not my purpose to speak to-night. The large spectroscope of the Cape Observatory, which we owe to the munificence of the late Mr. Frank McClean, was from the outset constructed with due regard to these precautions, so far as they could be foreseen, for the purpose of determining with the greatest accuracy attainable the radical velocities to ascertaining what evidences can thereby be successfully used, and its capabilities have been established in an investigation of the aberration constant of light as depending on the variations in the radical velocities of stars resulting from the earth's orbital motion. From a relatively short series of observations discussed by my colleague, Dr. Halm, this constant has been derived with a precision not inferior to that attained by the best series of older observations, and the capabilities of the method are yet far from exhausted. At the present time the instrument is being devoted to a series of observations of all such stars as are accessible in the Southern skies, whose spectra present sufficiently pronounced features to admit of measurement, primarily with a view to ascertaining what evidences can thereby be derived from a study of the radial velocities in regard to the systematic structure of the universe. A year or two must elapse before the present observing programme is completed, but a preliminary discussion of the observations already secured in combination with the published results derived from similar observations in the Northern Hemisphere has revealed the existence of anomalies similar to those found from the study of the transverse motions, anomalies which can only be reconciled with the two-drift hypothesis put forward by Kapteyn by the further hypothesis that though both drifts pervade the whole sky, they are not similarly distributed throughout it. At present, through scantiness of material, from a study of the radial velocities, we have been able to do little more than discriminate between the two halves of the sky, which contain respectively the greatest and the least proportion of second-drift stars. It is, however, a fact of some significance that the former corresponds very closely with that hemisphere which contains the Milky Way, suggesting the phenomena that Kapteyn's second drift might be identified with the galaxy. It was with a view to examining this suggestion, in the light of the evidence which could be secured from the transverse motions of the Bradley stars, that the discussions I have sketched to you to-night were undertaken by Dr. Halm. While they have established almost beyond question the rough features of distribution demanded to reconcile the radial velocity determinations, they further point to an even more detailed correspondence between the distribution of Galactic stars and the distribution of stars of the second drift, leaving but little doubt as to the identity of this second drift with the galaxy. I have pointed out how it is this second drift which exhibits evidence of structural unity. As regards the Milky Way, the mere appearance on any fine night affords evidence of a similar character, and it is on this account that we have been able to identify the Milky Way with the second drift rather than the first. The significance and origin of this structure is as yet obscure, but the more its details are elucidated and the essential features established, the nearer are we to an answer to the question: What is the Milky Way?

It is announced in the Electrician that a thunderstorm observatory has been established in Spain by G. J. de Guillen Garcia, in which atmospheric discharges, both local and distant, are detected graphically and acoustically. A wireless telegraph instrument is used for this purpose, because each lightning discharge is accompanied by electromagnetic waves similar to those used in wireless telegraphy. If there is a storm anywhere within a radius of 500 miles the observer is notified of the fact by the recording instrument. As most barometric depressions that pass over Western Europe come from the Atlantic Ocean, the new observatory gives meteorologists due warning of the approaching disturbance. By noting the intensity of the sounds produced in the receiver, and observing whether they grow more distinct or less, it is possible to determine the approximate course of a storm.

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SCIENCE NOTES.

Measures of the photographs of Jupiter taken during April, 1909, at the Lowell Observatory, Flagstaff, Arizona, have been made carefully for study of the dimensions of the planet and of its physical condition. The results are published in the Philosophical Magazine (19, 488). Determinations from five images on a plate taken April 14th, 1910, gave the ellipticity=1/14.8. Messrs. Slipher and Lowell, the authors of the paper, state that the poles of the planet are distinctly darker than the rest of the object. From the positions of the cloud belts it appears that those near the equator are symmetrically distributed about it, regardless of the declination of the sun at the time. This would suggest that Jupiter's cloud covering is self-produced, indicating great internal heat setting up currents which are persistent in their main features for long periods of time. The persistence of the red spot and surroundings for so many years would point to a plastic rather than a gaseous condition for the Jovian material. A very interesting feature is the series of wisps lacing the equatorial belt. They always proceed from black spots of a triangular shape set on the edge of the north or south tropical belts.

Biolcgists have been occupied with the question of the survival of cells when removed from the animal organism, and the subject is one of great interest, especially in surgery, where it is desired to keep tissues which are to be grafted, for a certain time. In France, M. J. Jolly has made some new researches on the subject and presented his results to the Biological Society. He already showed that we can observe the phenomenon of cell-division in the case of the red globules of the Triton upon a specimen of blood taken out fifteen days previously, and he also confined the results of Ranvier and Cardile as to the survival of the leucocytes when kept in glass vessels. Taking up his researches recently, he wished to base the proof of the survival of the cell not upon the structure, but by observing the phenomena of movement of the cell which are easy to distinguish, such as movements of the vibratory fibers, cell-division, contraction of muscular fibers and others. His first researches bore upon the leucocytes. He preserved blood which was taken from the heart of the Triton by means of pipettes and was kept constantly at the freezing point. At the end of four and one-half months he could still observe movements in the leucocytes, showing that they still retained life. The time in this case is exceptionally long, and is much more than Ranvier had observed, this being twenty-five days. The author believes that this time of four and one-half months can be much exceeded, and is now making further experiments.

The effect of magnetic and gravitational forces on the moon is considered by E. W. Brown in the American Journal of Science. Between the observed and computed place of the moon there is a difference which has been unexplained up to the present time. Its magnitude is too great for it to be attributed to error of observation, and Brown seeks to inquire if any force whose existence is only suspected may be the cause of the discrepancy. The period of the term is about 270 years, and its magnitude about 12 seconds. In the attempt to account for this, numerous computations have been made. A possible effect of magnetic attraction between the earth and the moon was examined by supposing the magnetic fields of the two bodies to be equivalent to that produced by straight solenoids symmetrical with respect to their centers of figure. The chief reason why the effect of magnetic attraction may be capable of observation arises from the fact that the resultant force varies as the inverse fourth power of the distance, while gravitation varies as the inverse square. From this the negative result was obtained that the unknown inequality cannot be produced solely by the secular motion of the magnetic axis of the earth. Difficulties also appear in supposing an oscillation of the lunar magnetic axis, or a variability of the product of magnetic moments, but it is suggested that a thorough consideration of the effect of magnetic attraction on the motion of the moon about its center of mass is desirable. An investigation into the gravitational effects of libration is not favorable to the view that a librational term contributes to the long-period inequality.

TABLE OF CONTENTS.

Page.

I. AERONAUTICS.—The Aeroplane in War.—By Our Paris Correspondent.—7 illustrations 243

II. ASTRONOMY.—Aims and Methods of Astronomical Research.—By S. S. Hough 255

III. CHEMISTRY.—A Possible Extension of the Periodic Law.—By O. Ivan Lee.—1 illustration 253

IV. ELECTRICITY.—A 1,000-Mile Wireless Station, III.—By Edward H. Guilford.—9 illustrations 240

V. ENGINEERING.—The Railways of the Holy Land.—By Harold J. Shepstone.—10 illustrations 248

VI. MISCELLANEOUS.—Students and Lumber Jacks 251
Science Notes 256

VII. PHYSICS.—The Metallic State.—By E. E. Fournier d'Albe 242
The Isolation of an Ion, II.—By Prof. R. A. Millikan. 254

VIII. PSYCHOLOGY.—Experiments in Animal Psychology.—By B. Forbin.—3 illustrations 252

IX. TECHNOLOGY.—The Coloration of Wood by Gases and Fumes.—By H. Wislicenus 250
Bagasse as a Paper-Making Material 251

X. ZOOLOGY.—Zoological Nomenclature 245